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ORE DEPOSITS AT THE CONTACTS OF INTRUSIVE ROCKS AND LIMESTONES; AND THEIR SIGNIFICANCE AS REGARDS THE GENERAL FORMATION OF VEINS.[1]

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In the recent discussions upon the origin of veins, two points of view have developed which are sharply contrasted with each other. By veins in this use is meant those deposits of ore and gangue, which have been brought into their present resting places as dissolved materials. Water is the well nigh universal solvent, but it may operate in the form of gas, and it may be associated with other gases or liquids. The probabilities are, however, that in the vast majority of cases water is the chief agent as practically all observers are agreed.

The two contrasted points of view differ with regard to the source of the water. The older view attributes the water primarily to the rainfall and therefore it is called meteoric water. After falling upon the surface the meteoric water divides into three parts. The first, a relatively small portion, passes directly back into the atmosphere by evaporation; the second, the largest portion, joins at once the surface drainage and is called the run-off; while the third, intermediate in amount, sinks into the ground and mingles with the ground waters. The ground-

[1] Paper read before the Mexican meeting of the International Geological Congress, September 10, 1906.

waters rise in springs, usually fed from no great depth, and themselves pass into the surface drainage after but a small subterranean journey. The ground-waters stand at depths below the surface which depend upon the amount of rainfall; upon the nature of the rocks, whether open textured or tight; and upon the topography of the region. Where the rainfall is abundant the ground-water roughly follows the outline of the surface, but it is less pronounced in its relief. It is nearer the surface in valleys than on mountain sides, and in a swamp it is actually at the surface. In the arid regions the ground-waters stand very deep. At Mapimi, Mexico, in the lead-silver mines they were first met at about 700 meters below the surface. Some observers have even questioned their necessary existence beneath excessively dry deserts. It may be therefore that locally they fail altogether.

While as a rule the ground-water level is fairly definite yet it sometimes displays, even in the same mining district, great irregularity. Experience at Tintic, Utah, in an arid district revealed the following relations. In monzonite the ground-water stood near the surface and was accompanied by very little of the oxidized ores; whereas in limestone, a kilometer or two distant, it had not been met at 500 meters. At Butte, Montana, secondary enrichment is evident down to 600 meters or more in granite and the water-level is quite irregular.

The section of active circulation and work of the descending meteoric waters, between the surface and the ground-water level was called by Posepny the vadose or shallow region. It has been long recognized by miners as the home of the oxidized ores. It is the place of the preëminent and well-established work of the descending waters. The deep-waters are relatively motionless, and their movements, so far as visible, are comparatively slow. But the really important feature of the ground-water as regards the filling of veins is the depth to which it extends. This remained a somewhat indefinite matter until Van Hise showed mathematically that cavities in the firmest rocks become impossibilities at about 10,000 meters. Obviously this depth marked therefore the physical possibility of range

for the ground-water. Down to some such limiting depth as an extreme it was believed by many to descend, to migrate laterally, to experience the normal increase of temperature with depth; the effect of pressure; the increased efficiency as a solvent peculiar to the conditions; and finally with a burden of dissolved gangue and ore to rise again, urged on by the "head" of the descending column. In its ascent it was supposed to fill the veins. The writer, however, some years ago suggested that mining experience indicated that the known ground-waters were comparatively shallow and seldom extended lower than 500–600 meters. This has been corroborated by a number of writers and John W. Finch,[1] recent State Geologist of Colorado, assigns the ground-water a vertical range of but 300–450 meters, divided into "Zone I., the gathering zone; Zone II., the discharging zone; and Zone III., the temporary and static zone." Beyond question some such summary as this corresponds to what we have learned by actual experience in mining. It is conceivable that during faulting and the formation of great dislocations this reservoir might be tapped into greater depths, and set in limited circulations through deeper seated rocks. But so far as these objections have weight they have greatly restricted the vertical range of the meteoric ground-waters as they were formerly believed to exist.

In contrast with the meteoric waters outlined above other waters are believed by many geologists to be given off by the deep-seated intrusive rocks, and are generally called magmatic. We are led to the belief in their existence by observing the vast quantities of steam and minor associated vapors which are emitted by volcanoes; by the difficulty of accounting in any other way for the amount and composition of certain hot-springs; and by the marked and characteristic association of almost all veins with eruptive rocks. That intrusive masses, in the form of dikes, sheets, laccoliths and batholiths have been genetically connected with the formation of veins is further brought out by the following general consideration which has

[1] John W. Finch, "The Circulation of Underground Aqueous Solutions and the Deposition of Lode Ores," *Proc. Col. Sci. Soc.*, 1904, VII., 193–252.

hitherto received too little attention. Aside from pegmatites, veins rich enough to be mined and even large veins of the barren gangue-minerals are extremely rare phenomena, when we compare the regions containing them, with the vast areas of the earth which have been carefully searched for them and which have failed to reveal them. As components of the earth's crust the useful metals except iron and aluminum are extremely rare. Some sharply localized, exceptional and briefly operative cause must have brought them into being. The universal circulation of the ground-water of meteoric origin fails to meet this test, since if it is effective we ought at least to find veins of quartz and calcite fairly universal in older rocks. In North America, moreover, by far the greater number of veins which have been studied date from the Mesozoic and Tertiary times. The ore deposits of older date are chiefly of iron and manganese, many of which can be satisfactorily accounted for by the reactions of the surface and vadose region or by magmatic differentiation.

The more one reflects upon these actual relationships the more is one driven to the eruptive rocks as the one exceptional agent, operating in any event by the contributions of heat and energy, and probably also by emissions of magmatic waters. As an important corroboration of the last conclusion the contact zones produced by eruptive intrusions upon limestones have great significance, and since they are very abundant in Mexico and the southwestern states and territories of the United States; since they very often have copper ores and sometimes zinc and lead associated with them; and since some important new facts have been recently brought out regarding them, the entire subject is herewith presented to the Congress.

Contact metamorphism in general has long been one of the most attractive fields of petrographic research, and several localities where the investigations have been carried out, such as Predazzo, in the Tyrol; Barr-Andlau in the Vosges Mountains; Mt. Willard in New Hampshire and Pouzac in the Pyrenees have become classic ground for geologists. We are all well aware that from aluminous rocks such as shales and slates,

andalusite, sillimanite, biotite and a few other minerals are produced; whereas from limestones, garnet, vesuvianite, wollastonite, diopside, epidote, wernerite, and some less common lime-silicates result. Until very recently the belief has been general among observers that only from aluminous and siliceous limestones could the zones of silicates result and that otherwise where the eruptive came in contact with pure carbonate of lime, white crystalline marble would be alone produced. It has also been the general belief that grossularite, the lime-alumina garnet was the principal if not the sole variety of garnet present, and upon this assumption, now generally disproved, the reasoning regarding the development of the zones was based. Thus alumina and silica are the components which would be needed for grossularite. They are as a matter of fact commonly present in earthy limestones. It was natural, therefore, to infer that only where *earthy* limestones were penetrated by eruptives would garnet zones be developed and that where the limestone was pure, crystalline marble would alone result. Somewhat strangely the one significant line of investigation which would cast light upon these views has but recently and in a few cases been pursued. That is to gather and analyze specimens of unaltered limestone which would represent as closely as possible, according to the stratigraphical relations, the original rock from which the garnet and other lime-silicates had been developed. And further to collect and also analyze the garnets themselves in order to discover whether they were grossularite or not. This method has now been pursued in three cases—the first by the writer for the zones at San José in the State of Tamaulipas, Mexico, the second by Waldemar Lindgren for Morenci, Arizona, and the third by the writer and C. G. Gunther in a manuscript shortly to be issued by the American Institute of Mining Engineers on White Knob, Idaho. The results in each case are as follows:

LIMESTONE AT SAN JOSÉ, TAMAULIPAS.

	1.	2.	3.
Insol	5.04	4.31	9.55
Al_2O_3 }	0.35	0.95	1.28
Fe_2O_3 }			
$CaCO_3$	94.55	93.83	88.92
$MgCO_3$	0.58	1.29	0.91
Total	100.52	100.38	100.66

No. 1. From the Vegonia claim, blue limestone.
No. 2. Furnace Quarry, blue limestone.
No. 3. White marble, recrystallized by the eruptive.

The insoluble material appeared to be practically silica, and was therefore not broken up by fusion. The iron and alumina are so low as to be of small significance in the formation of garnet.

LIMESTONES AT MORENCI, ARIZONA.

	1.	2.	3.	4.	5.	6.
SiO_2		1.00	1.34	0.30	1.00	
Insol	1.06					
Fe_2O_3 }	.92	2.71	1.66	{ 0.40 }	2.80	
Al_2O_3 }				{ 1.80 }		
$CaCO_3$	95.52	94.00	82.50	57.50	56.00	54.35
$MgCO_3$	.69		9.54	37.01	36.00	46.65
Total	98.19	97.71	95.04	97.01	95.80	101.00

All these are from W. Lindgren's monograph on Clifton-Morenci, Arizona, Professional Paper, 43, p. 71, U. S. Geol. Survey.
All are the Modoc limestone.
No. 1. Arizona Copper Co. Quarry.
No. 2. Detroit Copper Co. Quarry.
No. 3. Summit Shannon Mtn.
Nos. 4, 5 and 6. Morenci Smelter Quarry.

While the analyses vary widely in the amount of magnesium carbonate, all are low in silica, alumina and iron oxide; far too low in fact to yield much garnet.

LIMESTONE AT WHITE KNOB, IDAHO.

	1.	2.
SiO_2	14.77	1.38
Al_2O_3 }	3.68	1.01
Fe_2O_3 }		
$CaCO_3$	72.53	96.01
$MgCO_3$	8.89	1.36
Total	99.87	99.76

No. 1. Blue, unmetamorphosed limestone.
No. 2. White, crystalline marble.

In the first the silica is high enough to be important but the iron oxide and alumina are too low to be productive of much garnet. Wollastonite and diopside would probably result from recrystallization in this case. The White Knob occurrence is less significant than the others, because in it the pipes of garnet are in the intrusive rock and not in the limestone, a remarkable relation which will be referred to later on.

Taking the other analyses for such significance as they may have it is evident that they are too pure to yield much garnet of themselves. Contributions of silica, ferric iron and alumina from the eruptive would be necessary. We now turn to the garnets themselves, so far as known.

	San Jose.	Morenci.		White Knob.	
	1.	2.	3.	4.	5.
SiO_2	37.15	42.63	36.26	37.07	37.79
Al_2O_3	6.98	1.53	.78	17.42	11.97
Fe_2O_3	19.40	31.41	32.43	10.81	15.77
FeO		.30	.32	.68	1.31
CaO	32.44	23.37	29.67	32.77	32.57
MgO		none	none	.51	.37
MnO		.43	.27		.31
H_2O			.13	.14	.09
H_2O+			.44	.39	
$CaCO_3$	4.20				
P_2O_5			.06		
Sol. Fe_2O_3, Al_2O_3, etc.	.43				
Total	100.60	99.67	100.36	99.97	100.18

No. 1. Garnet, San José, Mexico, J. F. Kemp, Trans. Amer. Inst. Min. Engineers, XXXVI, p. 192.

Nos. 2 and 3. Garnet, Morenci, Ariz., W. Lindgren, Professional Paper, 43 U. S. Geol. Survey, p. 134.

No. 4. Light amber colored garnet, White Knob, Idaho, by C. W. Knight for J. F. Kemp and C. G. Gunther.

No. 5. Massive brown garnet, White Knob, by T. T. Read for J. F. Kemp and C. G. Gunther.

If the above analyses are recast so as to afford the relative percentages of the several garnet molecules the following results are obtained.

	1.	2.	3.	4.	5.
Grossularite ($3CaO, Al_2O_3, 3SiO_2$)	31.00	6.02	2.96	69.26	47.82
Andradite ($3CaO, Fe_2O_3, 3SiO_2$)	61.10	67.62	86.30	21.13	44.16
Almandite ($3FeO, Al_2O_3, 3SiO_2$)				1.61	2.99
Pyrope ($3MgO, Al_2O_3, 3SiO_2$)				1.44	1.31
Spessarite ($3MnO, Al_2O_3, 3SiO_2$)		.91	.79		.68
Hematite (Fe_2O_3)		7.30	4.80	4.25	1.90
Magnetite (FeO, Fe_2O_3)		1.00	1.00		
Kaolin	1.04			2.61	
Quartz	2.58	17.46	4.26		1.32
Calcite	4.20				
Water					.09
Total	99.92	100.31	100.11	100.30	100.27
Excess of SiO_2				.54	
				99.76	

In recasting Nos. 2 and 3, taken from Mr. Lindgren's paper, the calculated mineralogy varies in some particulars from the one observed and recorded by him. No magnetite is mentioned by him and the quartz is perhaps in excess of what would be inferred from his descriptions. But the great point is not affected, viz., to show the kinds and relative amounts of the several garnet molecules.

The percentages show that grossularite, so far from being the only variety of garnet present, is in general much inferior to andradite. In No. 4, where it is richest, the lightest colored, well crystallized garnets in the ore and gangue were selected for the sample. No. 5 is a much fairer illustration of the common variety in the zone. In No. 3 grossularite almost fails and in No. 2 it is in relatively small amount. It follows that in the discussion of the development of garnet zones, the chief importance is to be placed on ferric iron and not on alumina, or upon andradite rather than grossularite.

Upon the basis of assumed grossularite, it was natural to cite the earthy limestones such as are used in the manufacture of hydraulic cement as widely distributed types, which contain the silica and alumina in approximately the proportions required for grossularite. Such limestones are well known and in illustration of favorable varieties two selected American instances may be given, the first from New Lisbon, Ohio, and the second from

Belvidere, New Jersey. By their side may be further placed a third analysis of a theoretical mixture of quartz, kaolin and

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	CO_2	H_2O
1	36.69	15.17	4.82	15.24	3.73	16.07	7.60
2	27.90	7.89	1.70	32.10	1.40	26.78	
3	29.10	16.60		27.10		21.40	5.80

calcite which if recrystallized would exactly yield grossularite, $3CaO$, Al_2O_3, $3SiO_2$, by the elimination of CO_2 and H_2O. We see at once that the first two contain the necessary components of the third. A limestone having the composition of the first analysis and in which there is more silica than the grossularite molecule calls for, would doubtless yield diopside and wollastonite in addition to garnet. The low alumina of the second would lead to the same result. In each the percentage of iron oxide is so small that only a very subordinate amount of the andradite molecule could result, far less than would correspond to the garnet zones of whose actual composition we know.

While it is not difficult to find analyses of limestones favorable to grossularite because of high alumina, it is far less easy to discover those so high in the siderite molecule as to yield andradite, and if among limestones in general such ferruginous ones are rare, the chances that favorable beds will be cut by intrusives are all the smaller. The general probability that andradite zones are developed from richly ferruginous natural limestones becomes very small and the probability that the eruptive has contributed the iron becomes practically a certainty.

The iron-garnet is however not the only important consideration. Very often bodies of fairly pure magnetite of considerable size are found in the zones and confront the observer with the problem of their development. It is highly improbable that the eruptive rock will so constantly cut masses of pure limonite or siderite in deep-seated rocks and change them over to magnetite. On the contrary the iron ore is much more reasonably explained as a local phase of contact metamorphism—that is, its iron has come from the eruptive. Corroborative of the same inference is the very widespread and characteristic occurrence of specular hematite in the zones. One has only to read the

growing literature to be impressed with this fact. It recalls the familiar development of the specularite crystals in the cracks of Vesuvian lavas and around the fumarolic vents of other cones. Ferric chloride seems to be the form in which the iron is given off at or near the surface. Its reaction with atmospheric oxygen may then yield the specularite.

There is still another highly significant line of investigation. Some years ago Dr. Joseph Barrell,[1] working with Mr. Walter H. Weed upon the interesting deposits of the Elkhorn district, Montana, was led into a very acute and suggestive line of investigation. Contact zones are abundant in the district and are produced by the intrusion of a great mass of granite across a series of sedimentary rocks involving limestones. Dr. Barrell found contact garnet associated with a relatively impure stratum and contact marble with a purer one. He therefore took no issue in this respect with the generally accepted view. No analyses of either limestones or garnets were, however, made. Dr. Barrell was especially impressed with the porosity, which would be caused in the garnet zone by the recrystallization of silica, alumina and lime, originally in the limestone, and by the attendant elimination of the carbonic acid and water. Thus, assuming the necessary mixtures of quartz, kaolin and calcite and, for silicates other than grossularite, of limonite and magnesite, which would yield definite amounts of the several contact minerals, he determined by the use of molecular volumes the voids which would be left by the departure of the water and carbon dioxide in the production of garnet from quartz, kaolin and calcite. Theoretically for garnet, the voids amount to 47 per cent. of the mass, and for the other silicates, while somewhat less, yet in proportion. It was concluded that the contact zones, being of necessity so porous, would be very probable places for active circulations and for ore deposition.

But the results may be used as the basis of an argument in another way. It is admitted that these large percentages of cavities will result if materials originally present in the lime-

[1] "Physical Effects of Contact Metamorphism," *Am. Jour. of Sci.*, April, 1902, 290. Weed and Barrell, Twenty-second Ann. Rep. U. S. Geol. Survey, Part II., 399.

stones recombine and crystallize out; but on the other hand if as a matter of actual experience we do not find such a large proportion of spaces, but on the contrary discover that the garnet zones are on the whole very dense and firm rocks, we are driven to the conclusion that the garnet and other silicates have resulted, not from the recrystallization of impure limestones, but by actual addition of new material. Thus if to calcium carbonate we add silica and alumina or more correctly iron sesquioxide, the new additions will take the place of the evicted carbonic acid and produce a dense mass of silicates. So far as the writer's experience has gone, the latter character is the usual one possessed by the zones. They are prevailingly dense and compact, often are very hard rock to drill, and lead one to the inevitable inference that the silica and iron have come from the eruptive in far the largest part.

If, now from the several lines of evidence we believe that new material has been added, we may endeavor to formulate a conception of the method. First of all the question may be raised as to whether the eruptive has melted into its substance sufficient limestone to yield the zones which have then crystallized out from fusion. This view is opposed both by the sharp contacts afforded by the eruptive against the garnet zones; by the variability of the zones in mineralogy and by the fact that the necessary ingredients of andradite would not thereby be afforded. In almost all cases the eruptive is a highly acidic rock, a quartz-porphyry, or quartz-diorite-porphyry. The percentage in iron is very small, far below the requirements of the iron-lime garnet, and the general composition not at all adapted to yield the zones. On the contrary we are irresistibly led to the conclusion that from the intrusive rock has come either highly heated water gas or highly heated water itself in the closing stages, and that one or both of these have brought to the limestone the silica, iron oxide and alumina for the production of the lime-silicates. After the production of the garnet and its associates was well under way, they brought in also the copper and iron sulphides which are the commonest ores.

The silica and the other dissolved materials did not wander

farther from the eruptive because the limestone promptly intercepted them and locked them up in silicates; but undoubtedly carbonated water and carbon dioxide gas were yielded in great quantity, an inference which falls harmoniously in line with what we know of volcanic emissions.

At San Jose in Tamaulipas, a striking corroboration of this general conception was revealed a year or two after the writer's visit. A streak of garnet was followed into the diorite-porphyry and when well within the eruptive it opened out into a large cavity lined with beautiful crystals of orthoclase, exactly such as we find in the vugs of pegmatite veins. Apparently in this case we have revealed the very supply fissure from which the magma in its cooling stages gave forth the vapors or liquids which produced the zone.

If we are convinced by the phenomena of the garnet zones that water gas, and other gases or vapors are emitted from a deep-seated intrusive, we may question what would be the result if the wall rock were not limestone, but such a rock as quartzite, gneiss, schist or some older siliceous eruptive which would exercise no precipitating effect. In this event the water-gas would ultimately be condensed to the liquid form and provided with both metals and the elements of gangue minerals, would rise toward the surface until the inevitable fall in temperature and pressure would bring about the precipitation of both in veins. The solvents start under conditions strongly favoring solution; they proceed toward those strongly favoring precipitation. They present to us both agents and conditions well suited to bring to pass those end-results which of themselves are difficult to explain. Agents, moreover, are afforded of efficiency well suited to produce the ore bodies. Much support is therefore given to the conceptions of the "juvenile" or magmatic waters, which have been recently emphasized by Edouard Suess.

Even when the emissions from the eruptive yield the garnet zones, the waters greatly reinforced with carbon dioxide pass on to the upper regions. It is by no means improbable that in this way some carbonated hot-springs are caused and the

enormous quantities of carbonic acid gas with which we are familiar are afforded.

While the garnet zones most commonly yield pyrite, chalcopyrite and gold, they are yet known in instances to have galena, zincblende,[1] arsenopyrite[2] and some of the less common metallic minerals. Pyrite with copper and low gold values seems to be the most characteristic of the ores. We therefore infer that deep-seated intrusives are rather prone to send these forth. If we follow solutions of this character in their journey to the upper world, we must conclude that they are more directly significant for gold-quartz veins than for the other common types.

In their economic bearing, the contact zones, although sometimes rich enough to mine where they have not undergone secondary enrichment, as a rule require this process in order to make them available. Of this fact the two great Arizona camps, Morenci and Bisbee are illustrations. Where calcite is abundant malachite, azurite and cuprite appear, where the silicate minerals predominate, chrysocolla results.

The deposits at White Knob, Idaho,[3] which have been referred to above, differ from all others as yet known to the writer, in that the masses of garnet are in the form of pipes and chimneys almost all of which are within the eruptive rock itself and in instances 300 meters from the contact with the limestone. They have been explored some 200 meters below the outcrop and are found to come together in channels, much as the branches of a tree lead down to the main trunk. We are forced to the conclusion that the emissions from the deeper parts of the eruptive rock became charged with lime along the contact and passed upward through the igneous rock. The latter is a granite porphyry. Contributions from below of iron oxide and lime have changed it to garnet and other silicates, just as the reverse contributions of silica, iron oxide and alumina to the limestone would lead to the same result. While to a certain extent the process seems contradictory of our previous conceptions, it is yet the only one which fits the peculiar relations.

[1] Both these at Washington Camp, Arizona, as described by W. O. Crosby.
[2] The Nickel-Plate Mine, British Columbia, as described by W. H. Weed.
[3] These interesting ore-bodies will be the subject of a paper by C. G. Gunther, formerly engineer at the mines, and J. F. Kemp, and will shortly be issued by the American Institute of Mining Engineers.

EXPERIMENTS ON THE ACTION OF VARIOUS SOLUTIONS ON PYRITE AND MARCASITE.

H. N. Stokes.

INTRODUCTION.

The experiments described in this paper form part of an unfinished investigation undertaken by the writer before his transfer from the U. S. Geological Survey to the Bureau of Standards. While the work is by no means complete, the results would appear to have some geological significance and are published now in the hope that they may contribute somewhat to an understanding of the formation and decomposition of sulphides. As the writer will be unable to pursue the subject further, he hopes that the work may be continued and enlarged by other chemists working along geological lines.

Without attempting to discuss the geological bearings, the results may be briefly summarized as follows: Pyrite and marcasite are decomposed by circulating alkaline waters which leave hematite or hydrated ferric oxide and carry away the sulphur in the form of alkali sulphides and thiosulphate. The sulphides may react in another place with metallic salts giving sulphides; the thiosulphates may either remain unchanged or may react with copper or silver compounds, giving sulphides of these metals and alkali sulphates. This conversion of pyrite into hematite occurs in the absence of free oxygen; the occurrence of ferric oxides as transformation products of pyrite is, therefore, not in itself a proof of the action of aërated water or other oxidizing agents.

PYRITE AND MARCASITE WITH CUPRIC SALTS IN PRESENCE OF ALKALI BICARBONATES.

Cupric carbonate is not entirely insoluble in solutions of alkali bicarbonates; in fact, strong bicarbonate solutions readily dissolve it to a blue solution. The solubility of cupric carbonate, however, is not essential to its reaction with pyrite and marcasite,

as these are attacked by the alkaline solution itself, as will appear below.

The pyrite and marcasite used in the following experiments were finely ground and carefully purified by washing with ether to remove sulphur, digesting with hot dilute hydrochloric acid to remove ferric oxide, washing with dilute hydrochloric acid and water in an atmosphere of carbon dioxide and drying *in vacuo*.[1] The material then was transferred to the tube in which the experiment was to be made, the solution added, the air replaced by carbon dioxide and the tube sealed. In this way all oxidation was prevented.

About 0.2 gram marcasite was heated in a sealed tube filled with carbon dioxide for 14 hours at 160–170° with an 8 per cent. solution of cupric chloride to which potassium bicarbonate had been added to complete resolution of the carbonate. The solid product was chocolate brown, evidently from the presence of ferric oxide. The quantitative analysis of the solid and solution, which was made with the view of excluding the action of the air, and after making allowance for the small residue of undecomposed marcasite, which was determined, showed that 25.04 per cent. of the total sulphur had been oxidized to sulphuric acid. The equation

$$2FeS_2 + 6CuCO_3 + 2KHCO_3 = 3Cu_2S + Fe_2O_3 + K_2SO_4 + 8CO_2 + H_2O.$$

requires the oxidation of 25 per cent.

0.2 gram carefully prepared pyrite, treated in a similar manner and heated 23 hours at 180°, showed that 26.7 per cent. of the sulphur had been oxidized to sulphuric acid. The equation is the same as above, and the agreement with the theoretical is as close as could be expected.

An experiment with marcasite and solution of cupric carbonate in ammonium bicarbonate was carried out at 100° for 18 days. While the decomposition was incomplete the formation of ferric oxide and sulphuric acid was confirmed.

[1] See U. S. Geol. Survey Bulletin No. 186, p. 20.

MARCASITE WITH SILVER CARBONATE AND POTASSIUM BICARBONATE.

Marcasite heated with silver carbonate and potassium bicarbonate for 22 hours at 180° gave a residue containing silver sulphide and ferric oxide, while the solution contained sulphate and was free from other sulphur acids.

MARCASITE WITH LEAD CARBONATE AND ALKALI CARBONATE OR BICARBONATE.

One gram marcasite, 2 grams pure lead carbonate, 2 grams pure dry sodium carbonate and 20 c.c. water were heated in a sealed tube filled with carbon dioxide for 24 hours at 180°. The insoluble product contained crystals of galena. The filtrate was divided into two equal portions. The first portion, on heating with hydrochloric acid gave a precipitate of sulphur, while only a trace of barium sulphate was obtained. The second portion, after oxidation with bromine water gave an abundant barium sulphate precipitate, which was weighed. The insoluble residue was freed from the excess of lead carbonate by boiling with acetic acid in a current of carbon dioxide, to prevent oxidation of any unchanged marcasite and consequent precipitation of lead as sulphate. In the residue which remained the lead sulphide was oxidized and weighed as sulphate. The atomic ratio of sulphur in solution to sulphur in lead sulphide was 2:13.43 or nearly 2:14. The behavior of the solution, which deposited sulphur on acidifying and contained sulphate only after oxidizing indicates the presence of thiosulphate. This and the above ratio agree with the equation:

$$8FeS_2 + 14PbCO_3 + Na_2CO_3 = 14PbS + 4Fe_2O_3 + Na_2S_2O_3 + 15CO_2.$$

The amount of decomposed marcasite was calculated from the sulphur in solution plus that as lead sulphide, from which it appeared that the atomic ratio of sulphur in solution to iron in the decomposed marcasite was 2:7.73, or nearly 2:8 as required by the equation.

It will be observed that a marked difference exists between

the behavior of copper and silver carbonate and that of lead carbonate, in that in the case of copper and silver sulphate exclusively is found, while in the case of lead the product is thiosulphate with only a trace of sulphate. The explanation of this is to be found in the well-known fact that copper and silver salts easily decompose thiosulphates on heating, giving metallic sulphide and sulphate[1] while lead salts are without action on thiosulphates. Hence it is likely that thiosulphate is a primary product of the reaction in each case.

The reaction of metallic carbonates with pyrite and marcasite in presence of alkali carbonate solutions is still better exemplified by the behavior of zinc carbonate.

PYRITE AND MARCASITE WITH ZINC CARBONATE AND POTASSIUM BICARBONATE.

These experiments were made in essentially the same manner, zinc sulphide being white, it was easy to distinguish the ferric oxide by its color. The solutions were carefully analyzed, bearing in view the possibility that alkali sulphide, polysulphide, thiosulphate, sulphite and sulphate might be present. It is unnecessary to detail the somewhat complicated procedure employed and it may be merely stated that by treatment of different aliquot portions of the solution with cadmium hydroxide to remove sulphide, determining sulphuric acid in one portion directly and in another after oxidation, making an iodine titration with a third and determining the thiosulphate in another by heating with silver nitrate, it was found that sulphides, sulphites and sulphates were absent and that the total sulphur in solution was present as thiosulphate, which, moreover, gave the characteristic reactions. The residue was not further examined than to determine that all the pyrite or marcasite was decomposed, and that zinc sulphide and ferric oxide, mixed with excess of zinc carbonate were left. The equation in all probability is

$$8FeS_2 + 14ZnCO_3 + 2KHCO_3 = 14ZnS + 4Fe_2O_3 + K_2S_2O_3 + 16CO_2 + H_2O.$$

[1] $CuS_2O_3 + H_2O = CuS + H_2SO_4$, $Ag_2S_2O_3 + H_2O = Ag_2S + H_2SO_4$.

ACTION OF ALKALINE SOLUTION ALONE ON PYRITE AND MARCASITE.

In the above experiments the action of the alkaline solution on the pyrite or marcasite took place in the presence of a carbonate of a metal (Cu, Ag, Pb, Zn) capable of forming a stable insoluble sulphide. In the case of zinc and presumably in that of the other metals also, the reaction proceeded to completion, the final product being ferric oxide and metallic sulphide and in solution either thiosulphate or sulphate. In the following experiments, some light is thrown on the nature of the reaction.

One gram carefully prepared marcasite powder, 3 grams dry sodium carbonate and 30 c.c. water were sealed in a bomb tube in which the air had been replaced by carbon dioxide, and heated 22 hours at 185°. The contents were filtered. The filtrate had a yellowish color, due to the presence of alkali polysulphides, and after removal of these by cadmium chloride, was found to contain much thiosulphate.

One gram marcasite powder, 4 grams potassium bicarbonate and 40 c.c. water were similarly treated. The filtrate contained sulphide and polysulphide and after removal of these by cadmium chloride gave 0.0144 gram $K_2S_2O_3$ by titration and 0.0150 gram $K_2S_2O_3$ by direct gravimetric determination as silver sulphide.

One gram marcasite, 4 grams potassium bicarbonate and 25 c.c. water heated in the sealed tube 16 days at 100° gave sulphide and 0.0083 gram $K_2S_2O_3$ by titration and 0.0080 gram gravimetrically.

One gram marcasite, 3 grams dry sodium carbonate and 30 c.c. water were heated 30 hours at 180°. The yellow solution was found to contain 0.0119 gram $Na_2S_2O_3$ and for 1 mol. $Na_2S_2O_3$ there were 4.38 mols. Na_2S and 2.51 mols. Na_2S_2.

One gram pyrite powder heated as above with 3.5 grams dry sodium carbonate and 35 c.c. water gave 0.0072 grams $Na_2S_2O_3$, and for 1 mol. $Na_2S_2O_3$ there were 3.30 mols. Na_2S and 1.05 mols. Na_2S_2.

In the reactions in which the metallic carbonates are absent, the amount of thiosulphate is much less, while alkali sulphide and polysulphide appear. The reaction is undoubtedly complicated

and in part reversible. The experiments throw some light on what occurs, however. The formation of ferric oxide with zinc carbonate in an alkaline solution, in the absence of oxidizing agents, shows that the pyrite and marcasite may be regarded as ferric compounds. We may regard them as ferric sulphide containing an excess of sulphur, viz., as $Fe_2S_3.S$.

It is well known that free sulphur reacts with alkalies giving sulphide and thiosulphate, thus:

(1) $$4S + 3Na_2CO_3 = 2Na_2S + Na_2S_2O_3 + 3CO_2.$$

A further reaction would be that between sulphur and the sodium sulphide thus generated:

(2) $$S + Na_2S = Na_2S_2.$$

The experiments do not show which of the polysulphides are formed, but it will suffice to assume that Na_2S_2 is present. A third reaction would be that between the ferric sulphide portion of the molecule and the alkali:

(3) $$Fe_2S_3 + 3Na_2SO_3 = Fe_2O_3 + 3Na_2S + 3CO_2.$$

The third reaction is undoubtedly easily reversible and in fact does not proceed to any great extent if the ferric oxide is kept in contact with the generated alkali sulphide. The sulphide and polysulphide occurring in the solution, come mainly, and the thiosulphate entirely from the excess of sulphur in the pyrite and marcasite and it is clear that as several independent reactions are involved there can be no simple relation between the quantities of each product formed; an indeterminate portion of the excess sulphur acts according to (1) and the remainder according to (2).

As long as the decomposition products remain in contact no very considerable amount of ferric oxide can be formed. If, however, the sulphide in solution is continually removed, either by circulation or by precipitation, the transformation of the ferric sulphide into ferric oxide will eventually be complete. This is what occurs in the above experiments with copper, silver lead and zinc carbonates. The removal of the soluble sulphides by continually supplying fresh alkaline solutions can not be easily effected in the laboratory, where comparatively high temperatures

and small volumes have to be used. In nature, however, this may be easily realized and the transformation of pyrite into hematite effected without the aid of oxidation. Thiosulphates are occasionally found in mineral waters and while these may be formed by the action of alkali carbonates or alkali sulphites on free sulphur, or by the action of free oxygen on waters carrying suphides in solution[3] it is an hypothesis worthy of consideration that they may in part originate from the action of deep seated oxygen free alkaline waters on pyrite.

While the removal of the soluble sulphides by continually renewed fresh solution is not experimentally available a third method remains, namely, the volatilization of the sulphur as hydrogen sulphide. Alkali sulphides do not liberate free hydrogen sulphide on boiling; if, however, carbon dioxide is present, this decomposes the sulphide, the reaction, however, soon coming to equilibrium unless the hydrogen sulphide is removed. This can be effected at higher temperatures in closed vessels, free from air, by the presence of an absorbent entirely outside the liquid.

0.2 gram carefuly purified marcasite powder was placed in a 20 c.c. platinum crucible with 1 gram potassium bicarbonate and a little water. The crucible was placed within a platinum digester of 50 c.c. capacity, the lid of which could be clamped down airtight and on the bottom of which, outside the crucible, some lead carbonate was placed. The air in the apparatus was replaced by carbon dioxide and the lid at once closed. The digester was placed under water in an autoclave and heated 7 days at 180–200°. On opening, the marcasite was found to be completely converted into scaly hematite, while the lead carbonate outside the crucible and therefore never in contact with the solution had been converted into acicular crystals of galena, the excess of carbonate being crystallized to cerussite.

In a similar experiment with pyrite, in which the lead carbonate was replaced by cuprous oxide the pyrite was converted into hematite and the cuprous oxide into chalcocite, while the solution within the crucible contained thiosulphate.

[3] $2Na_2S + 4O + CO_2 = Na_2S_2O_3 + Na_2CO_3$, $Na_2S_2 + 3O = Na_2S_2O_3$, $Na_2S_5 + 3O = Na_2S_2O_3 + 3S$.

In a third experiment with the same apparatus, pyrite was used and the absorbent consisted of a series of discs of copper gauze placed on top of the crucible. After heating the digester under water in the autoclave for eight days at 200° it was found that water had leaked into the digester, covering the gauze, which was covered with crystals of chalcocite as much as 5 mm. long. The pyrite had been converted partly into hematite but mainly into magnetite, which, under a low magnifying power showed well developed octahedra, black and brilliant and strongly magnetic. The formation of magnetite in this case is doubtless to be ascribed to the hydrogen liberated by the action of the hydrogen sulphide on the metallic copper.

From the above experiments we may conclude that pyrite and marcasite can be completely converted into hematite by alkaline solutions, without the intervention of oxygen, provided the generated sulphides are removed by circulation. The solution, carrying sulphide and thiosulphate, coming in contact with soluble or insoluble salts of copper, silver, lead or zinc, will have the sulphide removed, and in the case of copper or silver, the thiosulphate will give rise to a further amount of suphide, the equivalent of sulphate taking its place.

Pyrite and marcasite are not the only sulphides which can generate thiosulphate in the above manner. Covellite was heated with 10 per cent. sodium carbonate in a sealed tube filled with carbon dioxide 22 hours at 180°. The solution contained abundant sulphide, polysulphide and thiosulphate. The reactions, in a simplified form, may be thus expressed:

$$8CuS + 3Na_2CO_3 = 4Cu_2S + 2Na_2S + Na_2S_2O_3 + 3CO_2$$

and

$$2CuS + Na_2S = Cu_2S + Na_2S_2$$

about one fourth the thiosulphate required by the first equation was found.

ACTION OF NEUTRAL SOLUTIONS OF METALLIC SALTS ON PYRITE AND MARCASITE.

ACTION OF CUPRIC SALTS.

In a former paper[4] I have shown that when pyrite is heated

[4] U. S. Geological Survey Bulletin 186, p. 44.

with neutral cupric chloride solution at 200° in the absence of air, the sulphur is completely oxidized to sulphuric acid. The reaction between pyrite and marcasite and cupric sulphate also results in the formation of sulphuric acid, but the sulphur is not completely oxidized, a portion remaining in the form of sulphides of copper. According as cuprous or cupric sulphide is formed, we may have the equations:

$$5FeS_2 + 14CuSO_4 + 12H_2O = 7Cu_2S + 5FeSO_4 + 12H_2SO_4$$

in which 30 per cent. of the sulphur is oxidized, or

$$4FeS_2 + 7CuSO_4 + 4H_2O = 7CuS + 4FeSO_4 + 4H_2SO_4$$

in which 12.5 per cent. of the sulphur is oxidized. In reality the reaction is more complicated, the cuprous ion being involved.[5] Cuprous sulphide is itself attacked by cupric sulphate, while cupric sulphide, at least in the form of covellite, is very resistant. The actual result of the experiments shows that the amount of sulphur oxidized to sulphuric acid lies between these extremes, so that it is likely that both reactions take place.

Carefuly purified marcasite was heated at 180° for 20 hours, with an accurately determined amount of neutral 10 per cent. cupric sulphate solution, under rigid exclusion of air, and the increase of SO_4 in the solution, as well as the composition of the residue determined. After making allowance for unaltered material, 18.4 per cent. of the sulphur was found to be oxidized.

In an exactly analogous experiment with pyrite 20.65 per cent. of the sulphur was oxidized.

An experiment with marcasite and neutral 10 per cent. cupric sulphate solution at 100° continued for 18 days, showed that 23.8 per cent. of the sulphur of the decomposed mineral was oxidized.

PYRITE AND MARCASITE WITH NEUTRAL LEAD CHLORIDE.

Purified pyrite and marcasite were heated with pure lead chloride and water in sealed tubes, filled with CO_2, for 12 hours at 180°. The solid product contained large quantities of galena

[5] This Journal, 1, 648 (1906).

and lead sulphate, the latter being decomposed and its SO_4 extracted by treatment with sodium carbonate solution.

The reaction is therefore presumably:

$$4FeS_2 + 7PbCl_2 + 4H_2O = 7PbS + 4FeCl_2 + H_2SO_4 + 6HCl.$$

From these experiments it would seem that the formation of free sulphuric acid through the action of neutral air free copper and lead solutions on pyrite and marcasite is a factor which can not be neglected.

NOTE ON THE IDENTIFICATION OF CHALCOCITE.

Chalcocite is readily attacked by ferric salts thus:

$$Cu_2S + 2FeCl_3 = CuS + CuCl_2 + 2FeCl_2.$$

The CuS thus formed shows the blue color of covellite. A fragment of chalcocite boiled for a moment with 10 per cent. ferric chloride solution acidified with hydrochloric acid becomes blue. The color appears to particular advantage on compact smooth chalcocite, but the rough mineral also becomes decidedly blue. A grey coating on chalcopyrite took on a deep indigo blue color. The same effect is produced, but not as satisfactorily, by boiling with 1–1 hydrochloric acid or allowing to stand a short time with concentrated hydrochloric acid, but this is apt to dissolve the coating completely. Enargite is entirely unaltered in appearance by the above treatment.[6]

[6] Knop. N. J'b., 1861, S. 533.

THE PEAT DEPOSITS OF NEW JERSEY.

HENRY B. KÜMMEL.

Recent investigations[1] by members of the Geological Survey of New Jersey have made available much detailed information regarding both the occurrence and the quality of the peat deposits of northern New Jersey.

Occurrence.—As is shown by the field work of Mr. McCourt

FIG. 1. Sketch map of Northern New Jersey showing distribution of workable peat deposits. (After McCourt.)

(see Fig. 1), peat beds of good quality and of considerable extent occur in Bergen, Morris, Sussex and Warren counties. Not all the swamps of these counties are peat swamps, but extensive de-

[1] "A Report on the Peat Deposits of Northern New Jersey," by C. W. Parmelee and W. E. McCourt. Annual Report of the State Geologist for 1905.

posits were found near Allendale and along Sprout Brook, in Bergen County; in the Black Meadows, Troy Meadows, and the Bog and Vly Meadows in Morris; the Vernon and Sussex meadows in Sussex; and the Pequest Meadows in Warren County. These deposits each range from 150 to 2,000 or 3,000 acres in surface area and depths of 8 to 10 feet were not infrequently found, although probably the average depth is less than this. Two somewhat distinct types of peat occur, a brown fibrous variety and a black, waxy, spongy one, but these varieties are not sharply differentiated from each other. The latter is the older and where both occur in one bog is found under the more fibrous form.

Moisture.—As is well known, all peat contains a large amount of water when first dug, which in some cases amounts to as much as 85 or 90 per cent. When exposed to the air, a large portion of the water evaporates, but there always remains some which cannot be driven out except at higher temperatures. It is manifest that the value of peat as fuel depends considerably upon the extent to which this moisture can be expelled by economical means for not only does each unit of the water replace a unit of combustible material, but a certain amount of the heat generated is consumed in vaporizing the moisture remaining. Consequently peat containing 25 per cent. of moisture, which should be the maximum for a good air-dried peat to be used as fuel, has something less than 75 per cent. of the heating power of a perfectly dry peat.

In this investigation the moisture content of 107 samples of air-dried peat was determined by Dr. Parmelee. The samples were spread out in thin layers, and exposed for several days to the room temperature. "A small portion, representing an average sample, was carefully taken and ground through a mill to such a fineness that it would all pass through a 100-mesh sieve. Two watch glasses ground on the edges to fit tightly together, with a brass spring to hold them firmly, were accurately weighed, and then five grams of the powdered sample were weighed and placed in one glass. This was placed in an oven which was kept at a temperature of 105° C. and the sample left there until,

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by repeated drying and weighing, no further loss of moisture was found. This operation generally required 96 hours. The weighings were always undertaken with the cover glass securely clamped over the sample by means of the spring. This was found necessary because of the very hygroscopic nature of the dry powder. The samples showed a wide range. The lowest amount of moisture in an individual sample was 6.09 per cent. The highest was 28.14 per cent. Considering the whole number of samples, it may be said that as the ash content increases the moisture content is lower; although the converse is not true, that a high moisture content indicates a low ash. It is not safe to apply the general rule to particular cases. The average moisture content of 107 samples having 50 per cent. or less of ash was found to be 15.52 per cent."[1]

Ash.—The amount of ash in peat is also of great importance in determining its value as a fuel. Not only is there the loss of the combustible material which is displaced by the ash, but of a certain amount of heat which is used in bringing the non-combustible matter to the temperature of the fire and maintaining the heat at that point. Furthermore, the cost of digging and transporting this ash has to be paid. As shown by the laboratory experiments, the ash in the samples tested varies greatly in amount, and is by no means always the same in peats which outwardly resemble each other closely.

The amount of ash was determined from the oven-dried sample, which was kept in a tightly-corked test-tube. A small amount, approximately 1 gram, was poured into a weighed platinum crucible,—the exact amount being determined by the difference in weight of the test-tube before and after. Ignition was carried out over a gas flame in the usual way and the residue weighed as ash. The percentage of ash was calculated on the basis of the air-dried material in order to obtain results comparable to what would occur under economic conditions. One hundred and seven samples were thus tested and the amount of ash was found to range from 5.04 to over 50 per cent.; those containing more than the latter figure not deserving the name of peat.

[1] *Loc. cit.*, p. 257.

Calorimeter Tests.—"The calorimetric tests of the New Jersey peats were obtained by the use of the Standard or Parr calorimeter. This apparatus consists of a hollow cylinder or bomb which may be tightly closed at either end. For a test, the bomb is charged with a small quantity of the powdered dry sample, crushed to pass through a 100 mesh. The quantity varied from one half to three fourths of a gram. This was mixed with sodium peroxide and potassium chlorate which furnished oxygen for combustion. The bomb, after filling, was immersed in a large cylinder containing a quantity of water—two liters. The large cylinder was placed in a fiber bucket having a wall between the large cylinder and the outer wall of the bucket. This arrangement provided an insulating air space between the large cylinder and the wall, and another between the wall and the bucket, which provision prevented temperature changes due to external causes. The bomb, when immersed, stood vertical, centered upon a pin so as to rotate easily. Four vanes attached to the sides, and an axle or stem of small size projected from the top of the bomb upwards. On the upper part of the stem a small pulley was attached, which was driven by a belt from a smaller motor. Within the bomb there were two metal poles attached to the cover and connected by a loop of fine iron wire of sufficient length to dip into the charge. This loop was heated to incandescence by the passage of an electric current, which thus ignited the charge. The completeness of the combustion is assured by the presence of the oxidizing chemicals mixed with the sample. The heat generated by this reaction radiates from the bomb and heats the surrounding water. By means of a delicate thermometer the rise in the temperature of the water could be noted and the calorific value calculated.

Since the determinations were made on samples dried at a temperature of 105° C., the results are higher than may be expected from the air-dried peat. The advantage of this method however is that all the samples may be more accurately compared since the amount of moisture remaining after air drying is dependent upon local conditions. Only those samples having 25 per cent or less of ash were tested. All tests were run in

duplicate and the results in all but two instances differed by less than one division on the thermometer used. That is, less than one twentieth of 1° F. In many instances the calculated difference was less than one two-hundredths of 1° F.

The results obtained by the use of this apparatus have not been checked by comparison with the results on the same sample using other types of the calorimeter. Since however it is known that this instrument gives accurate results with very similar fuels, such as lignite, brown coal, napthalene, etc., it is quite unlikely that the error from this source is greater than the experimental."[1]

Sixty-one samples were tested in duplicate, and results ranging from 5,876 calories as a maximum to 4,026 calories as a minimum were obtained. From a comparison of the detailed figures given in the table below it will be seen that with but few exceptions high calories accompany low ash, as was to be expected. The explanation of the exceptions does not appear from the facts presented but might be revealed by an ultimate chemical analysis.

In connection with these tests it is of interest to note the calorimetric value of some coals recently tested:[2]

	Calories.
West Virginia bituminous coal (12 samples)	7,549–8,495
Illinois bituminous (7 samples)	5,471–6,986
Brown lignites	4,716–5,385
Black lignites	5,728–5,987
Average of all coal and lignites tested (64 samples)	6,906

In making this comparison, however, it must be born in mind that the coal tests were made on air-dried samples, whereas the peat tests were made on samples dried at 105° C. This difference in procedure discriminates against the coal to a certain extent, so that the peat makes a better showing relatively than would have been the case had both sets of tests been made on the same basis. The greater the percentage of water present in the peat samples, the greater does this discrimination become,

[1] Loc. cit., p. 259.

[2] Parker, Holmes, Campbell, et al. U. S. G. S. Professional Paper 48, p. 196 et seq.

and it is necessary, therefore, in using the figures given in the table below to make allowance for the varying percentages of moisture present. In cases where the moisture is as much as 25 per cent., the calories should be diminished by nearly 30 per cent., to obtain results comparable with the coal test cited above.

Coking Tests.—Tests were made by Mr. R. B. Gage, chemist of the survey, for the purpose of securing data to indicate which of the New Jersey peats might be used in the manufacture of peat coke, and to determine the amount of volatile gases and fixed carbon in the peat. The standard method of determination was employed, *i. e.*, to heat 1 gram of the air-dried powdered peat in a platinum crucible for 3½ minutes over a bunsen burner with a low flame, which was then turned on full for the same length of time after which the crucible was cooled and weighed. The results are tabulated below. Since by this method the ash was included in the coke and weighed as such, samples containing high ash gave correspondingly high results for coke. It is necessary, therefore, to consider the ash content in comparing the figures for the coke.

Nitrogen Content.—"All the samples were examined by the Kjehldahl method for the total nitrogen present. Three grams of the powdered air-dried sample were found sufficient. These results may be useful for the manufacturer of filler for fertilizer, and the gas manufacturer using peat either in a by-product coking oven or with the Mond producer or similar systems for the recovery of the nitrogen. In our examination of 123 samples from this state, the lowest amount of nitrogen found was 0.74 per cent., the highest figure was 2.83 per cent. The average was 1.75 per cent. The results of the analyses are given in the table below."[1]

[1] Parmelee and McCourt, *loc. cit.*, p. 262.

TABLE SHOWING ALL TESTS OF NEW JERSEY PEATS.

Locality.	Locality Number.	Sample Number	Moisture, 105° C., Per Cent.	Ash, Air-dried Sample, Per Cent.	Calories.	British Thermal Units.	Nitrogen, Per Cent.	Coke, Per Cent.	Fixed Carbon, Per Cent.	Volatiles, Per Cent.
Pequannoc	.....	1	18.09	10.91	4,966	8,938	2.18	38.23	27.20	61.77
Allendale	5 a	2	15.00	18.89	4,388	7,898	2.13	41.57	22.68	58.43
Allendale	5 ab	3	14.11	5.04	5,896	10,611	2.17	29.20	24.16	70.80
Sprout Brook	8 a & b	4	16.42	64.17	.....	.....	1.60	.....	.....	.....
Sprout Brook	8 b	5	30.70	29.12	.....	.....	1.90	.....	.....	.....
Sprout Brook	8 c	7	9.08	50.43	.....	.....	0.95	.....	.....	.....
Hackensack	9 b	8	4.93	72.49	.....	.....	.....	.....	.....	.....
Hackensack	9 c	9	14.20	20.74	4,312	7,761	1.87	46.75	26.01	53.25
Springdale	10 b	10	7.25	57.55	2,238	4,028	1.31	.....	.....	.....
Springdale	10 e	11	13.28	24.43	4,041	7,274	2.40	.....	.....	.....
Buckmire Pond	11 a	12	6.31	67.70	.....	.....	0.82	.....	.....	.....
Newton	12 a	13	7.20	64.24	.....	.....	1.05	.....	.....	.....
Newton	12 a	14	11.89	30.54	.....	.....	1.70	.....	.....	.....
East of Newton	12 d	15	14.16	10.34	5,187	9,338	2.24	33.09	22.75	66.91
East of Newton	12 e	16	12.84	23.78	4,212	7,582	2.06	43.73	19.95	56.27
Sparta	13 ef	17	8.77	53.87	.....	.....	1.52	.....	.....	.....
Roseville	14 e	18	7.49	61.80	.....	.....	0.88	.....	.....	.....
Lafayette	15 e	19	12.26	23.29	4,092	7,365	2.01	44.85	21.56	55.15
Lafayette	15 e	21	9.64	26.12	.....	.....	1.58	.....	.....	.....
Lafayette	15 b	22	18.27	10.45	5,004	9,007	2.83	34.91	24.46	65.09
Sparta Junction	16 a	23	27.56	20.88	4,026	7,247	1.99	40.20	19.32	59.80
Sparta Junction	16 a	24	22.34	32 76	.....	.....	1.65	.....	.....	.....
Sparta Junction	16 d	25	9.73	29.22	.....	.....	2.37	.....	.....	.....
Sparta Junction	16 e	26	6.66	46.83	.....	.....	1.53	.....	.....	.....
Washingtonville	17 a	27	16.06	37.26	.....	.....	1.42	.....	.....	.....
Washingtonville	17 e	28	14.28	33.72	.....	.....	1.20	.....	.....	.....
Sussex	20 e	29	13.84	26.23	.....	.....	2.34	.....	.....	.....
Sussex	20 f	30	9.73	46.24	.....	.....	1.78	.....	.....	.....
Sussex	20 g	31	24.30	20.11	4,165	7,496	1.78	41.90	21.79	58.10
Sussex	20 h	32	12.89	51.06	.....	.....	1.30	.....	.....	.....
Sussex	20 l	33	10.14	49.09	.....	.....	1.59	.....	.....	.....
Sussex	20 m	34	15.99	11.38	4,946	8,902	2.34	37.95	26.57	62.05
Beemerville	21 a	35	14.12	17.23	4,814	8,667	1.53	41.40	24.17	58.60
Beemerville	21 e	36	14.20	20.82	4,199	7,558	1.86	39.38	18.56	60.62
Beemerville	21 e	40	12.50	23.03	4,212	7,582	1.77	44.35	21.32	55.65
Beemerville	21 g	41	10.69	38.08	.....	.....	1.65	.....	.....	.....
Wykertown	21 i	42	14.55	22.81	4,377	7,879	1.71	44.18	21.37	55.82
Sussex	20 o	43	14.45	28.69	.....	.....	2.10	.....	.....	.....
Sussex	20 o	44	7.57	7.27	4,589	8,260	2.00	36.11	28.84	63.89
Sussex	20 st	45	9.50	56.35	.....	.....	1.48	.....	.....	.....
Sussex	20 t	46	16.66	14.59	4,878	8,779	2.13	39.77	25.18	60.23
Van Sickle	22 a	47	14.01	13.04	4,986	8,975	2.25	40.01	26.97	59.99
Rockport	22 b	48	17.52	11.36	4,908	8,834	2.02	37.53	26.17	62.47
Vernon	23 a	49	12.98	38.69	.....	.....	1.71	.....	.....	.....
Vernon	23 e	50	12.55	46.27	.....	.....	1.76	.....	.....	.....
Vernon	23 h	51	11.09	50.15	.....	.....	1.04	.....	.....	.....
Vernon	23 j	52	13.74	36.91	.....	.....	1.79	.....	.....	.....
Vernon	23 r	53	17.74	25.26	.....	.....	2.46	.....	.....	.....
Vernon	23 q	54	18.55	14.40	4,707	8,473	2.73	36.92	22.52	63.08

TABLE SHOWING ALL TESTS OF NEW JERSEY PEATS.—*Continued.*

Locality.	Locality Number.	Sample Number.	Moisture, 105° C., Per Cent.	Ash, Air-dried, Sample, Per Cent.	Calories.	British Thermal Units.	Nitrogen, Per Cent.	Coke, Per ent.	Fixed Carbon, Per Cent.	Volatiles, Per Cent.
Beaver Run	25 d	55	15.70	25.86	.....	.....	2.03	.....	.....	.....
Beaver Run	25 e	56	14.42	28.08	.....	.....	1.90	.....	.....	.....
Harmonyvale	25 g	57	16.66	23.25	4,027	7,249	2.20	42.60	19.35	57.40
Stockholm	26 a	58	17.49	5.75	5,284	9,510	2.10	35.31	29.56	64.69
Dunker Pond	26 d	59	17.80	6.24	5,265	9,482	2.11	34.30	28.06	65.70
Wyckoff	27 b	60	16.77	24.70	4,049	7,287	1.98	45.90	21.20	54.10
Berkshire Valley	27 h	61	15.43	18.21	4,387	7,897	1.80	46.26	28.05	53.74
Berkshire Valley	28 a	62	11.87	37.42	.....	.....	1.78	.....	.....	.....
Berkshire Valley	28 b	63	13.87	24.95	4,276	7,697	1.79	47.10	22.15	52.90
Berkshire Valley	28 c	64	14.69	23.24	4,456	8,021	1.61	46.01	22.77	53.99
Berkshire Valley	28 c	65	14.04	20.10	4,800	8,640	1.54	41.95	21.85	58.05
Berkshire Valley	28 hl	66	13.63	24.38	4,300	7,739	1.48	45.20	20.82	54.80
Mt. Hope	29 c	67	14.32	16.44	5,117	9,211	1.54	42.65	26.21	57.35
Mt. Hope	29 d	68	15.26	5.14	5,645	10,162	1.27	43.85	38.71	56.15
Mt. Hope	29 k	69	13.60	27.46	.....	.....	1.60	.....	.....	.....
Mt. Hope	29 w	70	16.27	9.47	5,159	9,287	1.87	38.76	29.29	61.24
Kenvil	31 h	71	15.79	19.27	4,355	7,803	2.34	42.94	23.67	57.06
Ironia	32 i	72	14.59	9.34	5,488	9,877	1.17	37.64	28.30	62.36
Ironia	32 j	73	13.69	14.26	5,193	9,347	1.30	41.78	27.52	58.22
Chester	32 q	74	11.80	31.40	.....	.....	1.42	.....	.....	.....
Rockaway	33 g	75	16.20	10.54	5,057	9,102	2.11	32.25	21.71	67.75
Rockaway	33 g	76	14.17	16.46	5,049	9,088	1.88	41.10	24.64	58.90
Mountain View	46	77	10.44	51.65	.....	.....	1.22	.....	.....	.....
Chatham	35 l	80	15.21	33.07	.....	.....	1.50	.....	.....	.....
Chatham	35 lk	81	14.82	53.87	.....	.....	0.98	.....	.....	.....
Great Swamp	36 i	82	12.88	34.68	.....	.....	1.59	.....	.....	.....
Black Meadows	37 d	83	17.80	12.43	4,791	8,624	2.05	38.81	26.38	61.19
Great Meadows	37 e	84	17.81	10.84	4,885	8,794	1.88	37.45	26.61	62.55
Troy Meadows	41 b	85	11.42	49.18	.....	.....	1.25	.....	.....	.....
Great Swamp	38 b	86	7.58	66.40	.....	.....	0.74	.....	.....	.....
Great Swamp	38 f	87	9.59	50.48	.....	.....	1.26	.....	.....	.....
Great Swamp	38 i	88	11.80	45.92	.....	.....	1.34	.....	.....	.....
Great Swamp	38 l	89	16.19	13.86	4,947	8,905	2.07	40.09	26.23	59.91
Troy Meadows	41 i	90	13.27	39.02	.....	.....	1.36	.....	.....	.....
Troy Meadows	41 l	91	13.94	32.61	.....	.....	1.65	.....	.....	.....
Troy Meadows	41 s	92	17.54	10.60	5,272	9,490	1.46	37.80	27.20	62.20
Troy Meadows	41 b	93	17.86	13.44	4,901	8,820	1.98	38.96	25.52	61.04
Long Meadow	42 a	94	17.89	17.61	4,575	8,237	1.80	42.29	24.68	57.71
Hatfield Swamp	42 q	95	13.15	39.89	.....	.....	1.40	.....	.....	.....
Hanover	43 a	97	14.94	29.41	.....	.....	1.74	.....	.....	.....
Pequannoc	45 c	98	19.84	12.69	4,789	8,620	1.61	39.15	26.46	60.85
.....	.....	100	11.68	36.87	.....	.....	1.33	.....	.....	.....
Bog and Vly	47 e	101	15.26	25.19	.....	.....	1.58	.....	.....	.....
Bog and Vly	47 g	102	17.25	7.28	5,378	9,680	2.16	37.08	29.80	62.92
Cranford	48 c	103	14.18	32.37	.....	.....	1.50	.....	.....	.....
Rahway River	48 f	104	14.73	26.66	.....	.....	1.76	.....	.....	.....
Dismal Swamp	50 b	105	19.02	20.43	4,335	7,803	1.70	42.35	21.92	57.65
Newark Meadow	52 b	106	21.33	50.86	.....	.....	0.86	.....	.....	.....
Newark Meadow	52 b	107	11.00	44.34	.....	.....	1.24	.....	.....	.....

TABLE SHOWING ALL TESTS OF NEW JERSEY PEATS.—*Concluded.*

Locality.	Locality Number.	Sample Number.	Moisture, 105° C., Per Cent.	Ash, Air-dried, Sample, Per Cent.	Calories.	British Thermal Units.	Nitrogen, Per Cent.	Coke, Per Cent.	Fixed Carbon, Per Cent.	Volatiles, Per Cent.
Newark Meadow	53 k	108	18.59	20.06	4,347	7,833	1.92	43.55	23.49	56.45
Elizabethport	54 e	109	9.02	64.66	.....	.....	0.78	.....	.....	.....
Danville	56 f	110	20.84	11.04	5,234	9,421	1.98	36.90	25.86	63.10
Danville	56 z	111	27.70	13.31	4,562	8,213	1.96	40.26	26.95	59.74
Southtown	58 a	112	24.07	6.54	5,098	9,177	1.62	34.36	27.82	65.64
Bear Swamp	3 g	113	9.03	55.01	.....	.....	1.28	.....	.....	.....
Westwood	4 b	114	12.79	33.38	.....	.....	1.82	.....	.....	.....
Westwood	4 c	115	16.90	7.30	5,203	9,365	2.11	33.51	26.21	66.49
Southtown	58 b	116	20.90	13.42	4,795	8,632	2.52	36.83	23.41	63.17
Kerrs Corners	58 e	117	22.13	8.01	5,120	9,215	2.35	32.62	24.61	67.38
Kerrs Corners	58 k	118	21.89	7.72	4,982	8,968	1.59	36.70	28.98	63.30
Danville	56 a	119	28.14	8.62	4,953	8,915	2.45	33.14	24.52	66.86
Johnsonburg	57 a	120	21.63	15.82	4,317	7,772	2.27	36.35	20.53	63.65
Greenville	59 d	121	16.39	42.11	.....	.....	1.58	.....	.....	.....
Greenville	59 g	122	6.09	42.80	.....	.....	1.88	.....	.....	.....
Febletown	60 a	123	14.72	40.81	.....	.....	1.56	.....	.....	.....
Mt. Herman	60 e	124	22.68	16.71	4,568	8,224	2.13	36.46	19.75	63.54
Buttsville	61 e	125	16.82	10.41	4,863	8,753	2.65	34.51	24.10	65.49
Pigeon Swamp	62 k	126	24.25	20.40	4,539	8,169	1.72	37.25	16.85	62.75
Pompton Plain	63 c	127	13.82	38.50	.....	.....	1.48	.....	.....	.....
Pompton Plain	63 e	128	19.17	13.64	4,767	8,579	2.11	41.55	27.91	58.45
Pompton Plain	63 e	129	11.36	52.19	.....	.....	1.34	.....	.....	.....
Franklin Lake	63 f	130	12.50	8.34	5,521	9,938	2.03	36.28	27.94	63.72
Woodbridge Mfg. Co., Danville	.....	.....	18.82	10.40	4,926	8,865	2.62	34.40	24.00	65.60
Monmouth Junction	.....	.....	7.64	46.71	.....	.....	0.94	.....	.....	.....

Present Uses in New Jersey.—The chief use of peat in New Jersey at present is in connection with the manufacture of fertilizer chiefly as a filler and for mixing with dried blood. The use of peat for this purpose presents certain advantages both from a mechanical and chemical standpoint, which render its use desirable. Where peat is used as a filler the fertilizer shows less tendency to become lumpy, so that a more even distribution on the soil is readily obtained. Since all peat contains varying amounts of nitrogen, its use as a filler increases the nitrogen content of the fertilizer. It is true, indeed, that many authorities deny any value to peat nitrogen as a source of food to plants, when directly applied to the soil. If their view is correct, the consumer has good grounds for objections, when the manufacturer includes the peat nitrogen in his guarantee, along

with the high-grade organic nitrogen. Other authorities, however, assert that the peat nitrogen does become available for plant food, although not very rapidly, and that it has some money value for this purpose. However that may be, the fact remains that it is now used extensively for this purpose by manufacturers of fertilizer.

The Woodbridge Manufacturing Company have a plant located near Danville, on the Pequest Meadows, where the upper layer of peat is dug, dried and pulverized. The drying is done in an inclined cylindrical kiln, 30 feet long, 4 feet in diameter and takes from 15 to 20 minutes. The capacity of the plant was 11 to 12 tons per 12-hour day, but it has recently been enlarged.

The American Agricultural Chemical Company and the Alphano Company have recently started operations several miles northeast of Danville, on the west and east sides of the Pequest Meadows respectively.

Several attempts have been made to utilize peat as fuel. The most recent was made by the American Peat Coal Company, whose plant, located on the Bog and Vly Meadows, 2 miles west of Pequanac, was in operation during parts of 1904 and 1905. The freshly dug peat was put through a kneading and molding machine, of the type known as the Heinen Double Breaker, with a daily capacity of 50 tons. The peat after thorough mixing and kneading issued from the die in two bars, each 4½ inches square, which were cut by hand into briquettes, transferred on trays to the carrying belt which conveyed them to the drying house. No attempt was made to expell the water by pressure in the machine, but the briquettes were air-dried on shelves of wire netting for 2 to 4 days. The finished product was clean and hard, and could be handled without much breakage. The plant was never run to its full capacity and the market was mainly local, the fuel being used for domestic purposes chiefly. It sold at $3.00 per ton.

THE MAXIMUM RATE OF DEPOSITION OF COAL.[1]

GEORGE HALL ASHLEY.

In the preceding paper[2] in this series the attempt was made to ascertain the maximum deposition of the coals of the northern Appalachian coal field, it being held that the time necessary for the formation of each coal bed must be sufficient to permit the formation of that bed at the point of its greatest thickness. The sum of these maxima gave a total thickness of about 300 feet for that field. The purpose of obtaining this number was the belief that a study of the maximum rate of deposition of vegetal matter to-day in connection with the known maximum deposition of coal in a selected area might form the basis for estimating the time involved in the process.

Without going over the evidence in detail, it is apparent from a comparison given beyond that under the conditions existing to-day, the most rapid accumulations of vegetal matter result from the growth of more or less aquatic plants under certain favorable conditions.

Turning, then, to the consideration of the aquatic or semi-aquatic plants, we are concerned with the growth or rate of accumulation of the resulting carbonaceous matter. There are a great variety of such plants, varying greatly in their habits of growth. The accumulation of the remains of such plants may be broadly classed as peat beds. Under certain conditions these plants, on dying, undergo only partial decomposition and the gradual accumulation of carbonaceous matter results from the process. Such accumulations are commonly below water level in lakes, ponds, or along the seashore, but under certain favorable conditions of moisture and temperature they may be above water level on gentle slopes. While in some cases such accumu-

[1] Published by permission of the Director of the United States Geological Survey.

[2] ECONOMIC GEOLOGY, Vol. I., No. 8, p. 788.

lations may result from the growth of a single species of plant, generally a number of plants contribute to the result in any one case, sometimes without a predominance of any one form. In Europe the moss *Sphagnum palustre* predominates in these bogs. In America they are due to the growth of a number of aquatic plants, especially the *Polygonums* and some varieties of water lilies. In Asia wild rice, *Oryza Sylvestris,* is the dominant plant.

Our knowledge of the rate of accumulation of these plants is derived mainly from the north of Europe where the resulting beds have for centuries been dug for fuel. The rate varies with conditions, from that holding over the larger part of any area which does not permit the accumulation of any vegetal matter, except the mould of the fields and forests, which, from our standpoint, is insignificant, through those permitting the slow growth of peat, to those characterized by a most luxuriant vegetal growth with the necessary conditions for its preservation.

Europe contains many bogs in which the occurrence of ancient works of art or architecture, of which the approximate age may be determined, give opportunity to estimate the rate of growth. Rennie[1] reports the case of a Roman causeway under 8 feet of peat. At the outside this gives a rate of 1 foot in 200 years. Among other cases he gives one mentioned by the Earl of Cromarty, who in 1651 crossed a small plain covered with fir trees, still standing, but very old and decayed. Fifteen years later not a tree was to be seen and the plain was covered with green moss. Visiting the same place in " 1699 he saw that the whole was converted into peat moss from which the inhabitants took peat."[2]

Percy[3] cites Roman roads under 36 feet of peat which would require an annual growth of the peat of 5 to 6 millimeters. Lesquereux[4] claims that emerged mosses under the most favorable circumstances will show a growth at the top of the bog of

[1] Rennie, Rev. R., " Essays on Natural History and Origin of Peat Moss," London, 1807, p. 40.

[2] Rennie, *loc. cit.*, p. 66.

[3] Percy, John, " Fuel," p. 201.

[4] Lesquereux, Leo, Geological Survey of Pennsylvania; Ann. Report, 1885, p. 113.

1 inch a year, becoming less than one eighth inch lower down and still less in old bogs. He estimates that the average product of the compressed vegetation results in one foot a century. The immerged bogs he claims always grow more slowly and less regularly, many of them having shown a growth of only 5 or 6 feet from the time of Cæsar. Koller[1] gives the rate of growth in some peat bogs as 75 centimeters in 100 years. Yet others, he says, give the same thickness in 30 to 50 years, while in still other localities as high as 2 meters have been formed in 70 years. Giekie[2] cites some cases of extremely rapid growth. In one case in the west of Rosshire at least 4 feet of peat was formed in 48 years. In the valley of the Sonne 3 feet will grow in 30 to 40 years. On a moor in Hanover a layer of peat 4 to 6 feet thick grew in 24 years. Examining into these cases of very rapid growth, it appears that in most instances they are the result of growth under peculiarly favorable circumstances. In a growing bog it has long been the custom, in order to continue the bog, to cut the peat in the form of pits, these pits often being 6 by 20 feet in dimensions, and sometimes smaller, though often larger. After the removal of the peat, the pit is allowed to fill with the marsh water and in a comparatively short time the peat will be renewed so that it can again be dug for fuel. Rennie[3] quotes cases where a ditch 10 feet wide and 7 feet deep becomes so filled with aquatic plants in 10, 20, or 30 years that men and cattle may safely pass over it; "though the bottom be loose and liquid, it is solid on the surface, and in an age or two the whole would be ripened into turf." In shallower pits the growth is even more rapid so that in some cases good peat may be cut out of the pits within 30 years after their first digging. Percy[4] quotes one case in Ireland in which a plot of ground was shown by an Ordnance map made in 1842 to be entirely covered with water. In April 1872 the same area was found to contain a bed of peat 15 feet thick over which a railroad passed. This

[1] "Torfindustrie," p. 11.
[2] Giekie, Archibald, "Text-book of Geology," 2d edition, p. 443.
[3] Rennie, *loc. cit.*, p. 127.
[4] Percy, *loc. cit.*, p. 201.

case has been cited as an instance in which 15 feet of peat grew in 30 years, or at a rate of 6 inches a year. It may be questioned, however, if there may not have been a considerable accumulation of peat under the water surface at the time that the map was made. Rennie[1] quotes from a letter by Dr. Graham, of Aberfoyle, as follows:

"With regard to the peat holes or pits which within these 22 years I have had dug myself, many of them are already so overgrown with *Sphagnum* that they present an almost solid substance. Those that had been dug by one of my predecessors between 1732 and 1770 have been long ago renovated and they have actually had peat from them again." (Letter not later than 1807.)

The figures given indicate that under the most favorable conditions peat has been known to form at as high a rate as 1 foot in 5 years. These conditions include not only favoring temperature and humidity, but stagnant basins so small and shallow as to restrict or eliminate the action of waves or currents, experience showing that the rate of growth is less in larger or deeper basins. On this account it is believed that a rate of 1 foot in 10 years is a fair average maximum for normally favorable conditions.

But because 3 feet of peat may form in 30 years does not imply that 30 feet will form in 300 years. Lesquereux has already been quoted as saying that 1 inch of growth at the surface was equal to one eighth inch farther down, and still less on old bogs. He estimates that a growth of 1 inch in a year at the surface will be equivalent to 1 foot of compact matter a century. Rennie quotes De Luc to the effect that 1 inch at the base is equal to 2 feet of material at the surface. The matter may be approached in another way. Young peat may contain as high as 90 per cent. of water; 85 per cent. being a common figure. Such peat, after air-drying, for two or three weeks, will contain from 15 to 30 per cent. of moisture, about 20 per cent. being a fair average. On the drying, a brick with a volume of 120 cubic inches will shrink to 24 cubic inches and in weight from 6 pounds to 1.3 pounds. In this condition it may have a specific gravity as low

[1] Rennie, *loc. cit.*, p. 317.

as .11, but averages near .30 (this is the apparent specific gravity, or the weight of a given volume of peat, including air spaces as compared with the weight of a similar volume of water. The peaty matter alone will always sink in water, so has a specific gravity of over 1). In contrast with this, old peat well compressed in a bog may not show over 30 per cent. of water, and when air-dried will show a specific gravity of up to 1.03, according to Karmarsh.[1]

Kane[2] gives the specific gravity of air-dried peat from the upper part of a bog at Phillipstown, King's County, Ireland, 18 feet deep, as .405; the lower part of the same bog gave .669. The upper part of a bog at the Wood of Allen, Ireland, gave .335, and the lower part .655. The upper part of the bog showed as much as 90 per cent. of water and the lower only 30 per cent. before air-drying.

In addition to the loss of water, the peat has also suffered a loss through the extraction of a certain amount of its carbon, hydrogen, and oxygen in the form of carbonic acid, marsh gas, and water of constitution. Kane gives the following analyses of peat from the upper and lower parts of bogs:

	Sp. Gr.	C.	H.	O.	N.	Ash.
Surface peat, Phillipstown	.405	57.5	6.8	32.2	1.42	1.9
Bottom peat, Phillipstown	.669	58.4	5.9	31.4	.85	3.3
Surface peat, Wood of Allen	.335	58.2	6.4	31.3	1.23	2.7
Bottom peat, Wood of Allen	.655	56.2	5.3	29.8	.75	7.9

The following analyses from Johnson[3] show some of the steps in the change:

	C.	H.	O.	N.
Sphagnum moss	49.8	6.5	42.4	1.1
Peach	49.9	6.1	43.1	.9
Poplar	50.3	6.3	42.4	1
Oak	50.6	6	41.1	1.3
Sphagnum in peat, light brown, porous	50.8	5.8	42.5	.77
Peat, porous red brown	53.5	5.9	40.5	
Peat, heavy brown	56.4	5.3	38.2	
Peat, dark red brown, well decomposed	59.4	6.5	31.5	2.5
Peat, black, very dense and hard	59.7	5.7	33	1.5
Peat, black, heavy	59.7	5.2	32	2.5
Peat, brown, heavy	62.5	6.8	29	1.4

[1] Johnson, "Peat and its Uses," p. 95.

[2] Report on the Nature and Products of the Destructive Distillation of Peat, etc.

[3] *Loc. cit.*, p. 24.

Websky analyzed gas from a bog at Grunewald obtained 1 foot below surface of bog with the following results:

	Volume.	Weight.	Carbon.	Hydrogen.
Carbonic acid	2.97	5.57	1.52	
Marsh gas	43.36	30.04	22.53	7.51
Nitrogen	53.67	64.39		

Bischof[2] has estimated this loss to vary from 21 per cent. to 54 per cent. according to the assumed character of the lost material, the loss being in the form of carbonic acid, water, and marsh gas. Twenty-five per cent. may be taken as a conservative estimate. (See tables beyond).

Roughly, then, in a deep bog, such as must be postulated to yield the thick beds of coal, the 1 foot of peat at the surface laid down in 10 years will later shrink to 3 inches, due to the loss of moisture; its loss by partial decomposition has been estimated at about one fourth of the vegetal matter, of which it is composed, but as its specific gravity increases to about twice what it was before compression, the original 3 inches will be compressed to, say ½ of ¾ of 3 inches, or 1⅛ inches, and probably less in very deep bogs. This gives about 1 foot in a century as the rate of accumulation of the buried peat, substantially in agreement with the rate given by Lesquereux.

Having now obtained a figure representing the maximum rate of deposition of peat in deep bogs, if it can be determined how much coal 1 foot of compressed peat will yield, we will be in a position to estimate the time interval involved. This third factor of the problem is the most difficult of approach and the most uncertain in the results yielded. As with the preceding, it may be approached from the side of the laboratory by a comparative study of the analyses of the coal and peat or from the field by observing the thickness of coal deposited in basins of unequal depth, or the differential shrinkage with a variable thickness of coal.

From the laboratory side a comparison of the coal and peat shows: first, a loss in moisture; second, a loss through the con-

[1] *Erdmann's Journal*, 1864, p. 76.
[2] "Chemical Geol.," pp. 280 et seq.

tinuance of the destructive distillation; and third, a gain in specific gravity.

Taken as a whole the peat bed will vary in the amount of moisture from 90 per cent. at the surface to about 30 per cent. near the bottom. In a thick bed the average will probably come much nearer the lower limit, say 35 to 40 per cent. The coals of the northern Appalachian field are dry coals, ranging from 2 to 6 per cent. in moisture. Roughly, then, it may be said that the peat will lose one third of its weight through the loss of water in changing to coal.

Taking the mean of 67 analyses of coal as giving carbon 82.2, hydrogen 5.5, oxygen 12.3, Bischof[1] has estimated the loss in the change from wood to coal.

The problem has been worked out in three different ways. In the first case the loss is assumed to be in the form of carbonic acid and marsh gas; in the second carbonic acid and water, in which the hydrogen has been oxidized by outside oxygen; and in the third, carbonic acid and water, the oxygen being obtained from the wood. The probably true case in which carbonic acid, marsh gas, and water are all separated, is an indefinite problem which admits of several solutions. One set of Bischof's figures, from which others do not differ materially, is as follows:

	Case I.			Case II.			Case III		
	Wood	Loss.	Coal.	Wood.	Loss	Coal.	Wood.	Loss.	Coal.
C	49.1	— 31.0	= 18.1	49.1	— 14.80	= 34.30	49.1	— 4.3	= 44.8
H	6.3	— 5.1	= 1.2	6.3	— 4.01	= 2.29	6.3	— 3.3	= 3.0
O	47.6	— 41.9	= 2.7	44.6	— 39.45	= 5.15	44.6	— 37.9	= 6.7
	100	78	22	100	58.26	41.74	100	45.5	54.5

Bischof inclines to the third case as nearer the true one.[2] Yet, notwithstanding, nearly, if not quite, all the calculations seen by the writer which are based on these figures use the first one without any reference to the others.

The same formulæ applied to analyses of wood and peat gave losses in the change from wood to peat which may be compared with the losses obtained in estimating the production of coal from wood. This is done in the following table in which A gives the losses in the three cases in the formation of coal as in the preced-

[1] "Elements of Chemical and Physical Geology," Vol. 1, p. 276.

[2] *Loc. cit.*, p. 286.

ing paragraph, and B the losses in the same cases in the formation of peat.

	A.	B.	Difference.
I	78	54.1	23.9
II	58.26	31.8	26.46
III	45.5	21.75	23.25

From these figures it would appear that in the formation of coal from peat there is a loss of about one fourth of the original vegetal matter in the formation of the peat, this further loss means a withdrawal of one third of the vegetal matter remaining in the peat.

The weight of a cubic foot of peat from the lower part of the bed will average about 50 pounds. Withdrawing one third of that weight for the loss of water and one third of the remainder for the loss by distillation, there is left, roundly, 25 pounds. A cubic foot of coal from the Appalachian field on the average will have a weight of about 87½ pounds; therefore, to make one foot of such coal will require 3½ feet of well-compressed peat.

Turning to the field study of the problem it is evident that

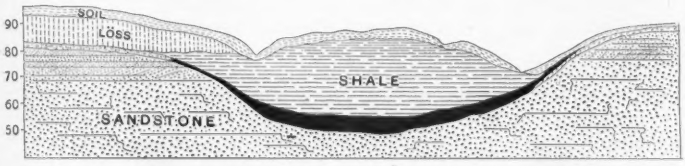

FIG. 2. Section of small coal basin exposed in quarry face at Redrock, Marion Co., Iowa. (After C. R. Keyes.)

there is here a large field for study. A few cases will be given, not so much for the results obtained, which are rather discordant, as suggesting methods of approach. Of the occurrence of coal in basins it will suffice to give three examples, in none of which have we all the data desired. Fig. 2 shows a section of a small coal basin exposed in a quarry face at Redrock, Marion County, Iowa, described and figured by Charles R. Keyes.[1] The coal is 6 feet thick and overlain by 30 feet of shale. The original depth of the basin is not quite clear, but was not less than 25 feet,

[1] Iowa Geological Survey, Vol. II., p. 53.

and probably nearly, or quite, 40 feet. On this basis each foot of coal represents from 4 to 7 feet of original vegetal matter.

Figs. 3 and 4 from measurements made by the writer in 1897

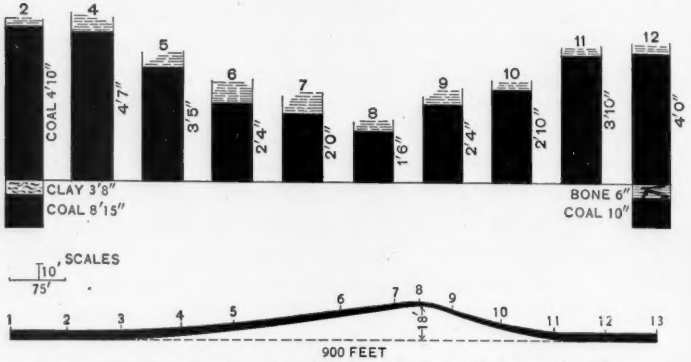

FIG. 3. Section showing the thinning of the coal in passing from one basin to another. From measurements made in Crawford No. 1 mine, Parke County, Indiana.

in the block coal field of Indiana show the thinning of the coal in crossing the ridges which partially separate the adjacent basins. In these cases, to determine the factor of shrinkage, the following formula was used: $Ax = Bx + C$, in which A is the thick-

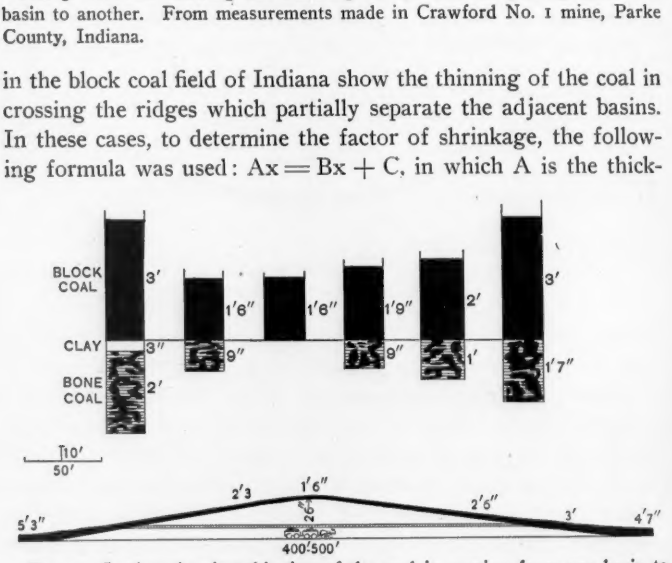

FIG. 4. Section showing thinning of the coal in passing from one basin to another. From measurements made in Gowtsherrie No. 3 mine, Clay County, Indiana.

ness of the coal in the basins, B, the thickness on top of the ridge, C, elevation of the ridge above the level in the center of the basins, and x, the reciprocal of the factor of shrinkage. The results gave, in the cases shown, in Fig. 3, $x = 4$; in the other case $x = 8\frac{2}{3}$. In the latter case allowance was made for the bony character of the lower bench of coal. In the preceding case it is not known whether the lower bench runs out on the ridge, but it is assumed to do so. Again it is not now known whether the general dip, possibly involving both basins, may not have affected the figures given for the height of the divides. The heights given are from the mine track which it is assumed was laid to grade from one basin to the other in each case.

In these cases it is evident that the factor of shrinkage will vary with the depth of the basin. A shallow basin, in which little compacting of the material takes place during its growth, may show a large factor of shrinkage. In a deep basin, on the other hand, requiring a long time to fill, the bulk of the material is well compressed before the period of growth ceases, and the factor of shrinkage after the growth ceases will be much smaller.

In Figs. 5 and 6 are given two illustrations of an interesting type of rock roll. Evidently an erosion, or open water channel, existed in the top of the partly consolidated coal bed previously to the deposition of the regular roof. Sand was washed into this and at the same time stringers and films of carbonaceous matter were also carried out into the sand filling. Then the normal shale roof was laid down. Apparently some shrinkage took place after the laying down of the shale roof. Owing to the practically non-shrinkable character of the sand, that portion of the bed where the channel had existed did not as a whole shrink as much as the parts of the bed where it was all carbon. In the first case in Fig. 5, the shrinkage of the coal appears to have been from 2 to 1; in the case in Fig. 6 from 11 to 8. In these cases the coal may have been under compression by a considerable depth of water before the washing in of the shale roof. These instances are given merely as suggestions for future study.

Another possible line of inquiry is through the study of the local variations of regular beds. Nearly every extensive mine

finds local "swamps," or low places, which in regions of very gentle dips may not drain themselves. In such "swamps" the coal is almost always much thicker than normal. Careful level-

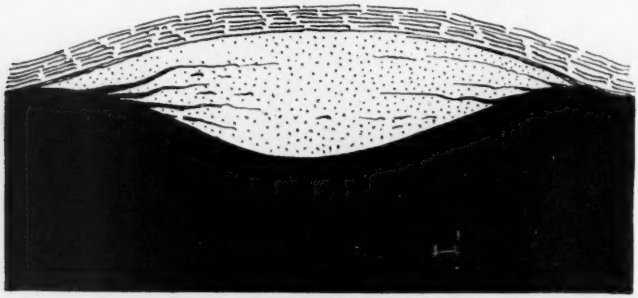

FIG. 5. Rock roll, from Crawford No. 1 mine, Parke County, Indiana.

ing to determine accurately the shape and depth of the low place with accurate measurements on the coal, both in and on either side of the "swamp" ought to throw some light on the problem. In other cases it may be possible to detect a response in the thickness of the coal to what appears to be a low area in the bottom of

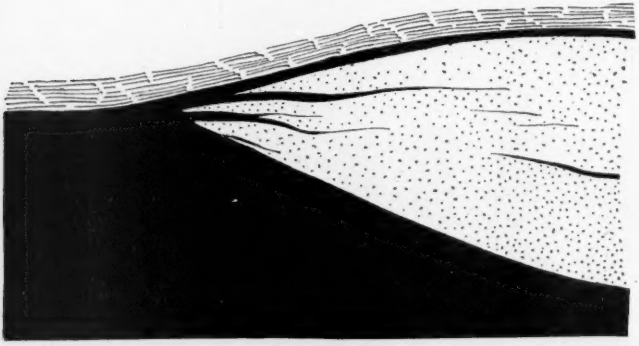

FIG. 6. Rock roll near Lafayette furnace, Clay County, Indiana.

the old bog, as judged by the fact that the interval to some underlying regular stratum is less at that point. Mr. W. T. Griswold in some recent work has noted such a case a little to the southeast

of Steubenville Ohio. He finds the interval from the Pittsburg coal to the Ames limestone to be very constant for any limited area, the range in any one township usually being under 6 feet. At the point in question he finds this interval to be 35 feet less than the normal for that region. At the same time at that point he finds the Pittsburg coal to be 20 inches thicker than normal, the bottom bench being 20 inches as against 12 to 14 normally, the bearing-in bench being about 10 inches as against 4 to 6 inches normally, and the partings 1 inch as compared with ½ inch normally. Apparently the 35 foot extra depth of the bog was responsible for the added 20 inches of coal, or 1 foot of coal resulted from 20 feet of vegetal matter.

In summary, remembering that the writer's purpose, as stated in the first paper, has been not so much to reach a figure that should be authoritative, as to suggest for criticism and correction a method of approach, the factor 3 has been selected as representing not the shrinkage of the whole bed, but the number of feet of well compacted, deeply-buried old peat necessary to produce 1 foot of bituminous coal of the general character of the Pittsburg coal of Pennsylvania. Applying this to our estimate that 1 foot of such peat requires a century for its deposition, and we have 300 years as the time necessary for the laying down of 1 foot of average bituminous coal; at this rate the Pittsburg bed, where 7 feet thick, required 2,100 years for its accumulation and 4,000 years in its best development in the Georges Creek basin of Maryland.

It is of interest to compare this figure with the result of computations based on the growth of land plants. Shaler[1] estimates the present rate of accumulation of carbonaceous matter (leaves, boughs, bark, decayed roots, and seeds) for forested areas at one tenth of an inch a year, or 10 inches a century, 1,000 years being required to produce 8 feet. The computation is simplified by taking only the carbon of the plant growth. Liebig estimates 1,000 pounds of carbon may be harvested yearly from a morgen of the surface, a little less than two thirds of an acre. Lewis and Gilbert estimate a crop of wheat to yield 2,500 pounds to the

[1] Shaler, N. S., "Fresh Water Morasses of the United States," Tenth Ann. Rept. U. S. Geological Survey, p. 262.

acre. Estimates on the forest growth in Germany give 2,700 pounds, while in the West Indies a crop of sugar cane may give from 2½ to 5 tons of carbon per acre.[1] Estimates on the growth of other field crops, especially alfalfa and forage, give about 5 tons of carbon to the acre as a maximum, the average in most crops being from ½ to 1½ tons. The figure given means the obtaining of at least 12½ tons of air-dried vegetal matter per acre.

Turning again to Bischof's figures, they give the loss in carbon in changing wood to coal as between 10 per cent. and 60 per cent.; if 20 per cent. be selected as conservative, there is left 4 tons of carbon. An acre of coal 1 foot thick of specific gravity 1.40 contains 1,600 tons of coal. Of this 75 per cent. for our average bituminous coal, will be carbon, amounting to 1,200 tons for the acre. If 4 tons a year of carbon becomes available in the production of coal, 300 years will evidently be necessary for the production of 1 foot of coal one acre in extent. In other words this estimate on the assumption that there is no loss of vegetal matter, gives practically the same result as our first computation, but, taking into account the loss by decay on the land and in transportation, it is evident that 1 foot of coal derived from land plants under the conditions of growth assumed would represent much more and probably many times more than 300 years. In fact, any theory of the deposition of coal in which the carbonaceous matter is supposed to be derived from the growth of land plants on land and their subsequent transportation and deposition under water, with the necessarily accompanying large loss from the decay in place and in transit must be at a disadvantage as far as rapidity of accumulation is concerned with the theory of its coming from the growth of water plants in place. Without arguing for or against the competency of the land derivation of the carbon of the Appalachian coal measures, it is clear that its consideration brings in indeterminate time factors which, therefore, place it outside the scope of the present inquiry. It is also patent that any figures based on this theory are liable to greatly increase the time result being sought.

[1] *Nature*, XXI., p. 211, 1877.

Turning to the Appalachian field as a whole, where it has been estimated that 300 feet of coal as a maximum were laid down, and it would appear that 90,000 years, say roundly 100,000 years, were required for the laying down of this coal. As stated at the beginning, this can be accepted only on the basis of the existence in carboniferous time of conditions no more favorable in kind for the growth of plants than at present, though with undoubtedly very different physiographic and other geologic conditions. Again it must be remembered that the figures are based on the maximum rate of growth, for, to consider slower growth would render the problem indefinite. Therefore, the figures given, if the data and the methods used are reliable, is a minimum.

THE VALUE OF COAL-MINE SAMPLING.

MARIUS R. CAMPBELL.

INTRODUCTION.

It is always satisfactory to have one's conclusions verified, especially when they were originally based on scanty, or insufficient data and are confirmed by more refined methods of work and by a great mass of evidence that makes them irrefutable. This statement applies particularly to some provisional conclusions which the writer published regarding the value of coal-mine sampling for the purpose of determining the commercial value of a coal, and to its verification by recent work along the same line.

At the close of the St. Louis Exposition the writer endeavored, in a short paper read before the Washington meeting of the American Institute of Mining Engineers,[1] to sum up the results of mine sampling as compared with carload sampling after the coal had been shipped to the Fuel-Testing Plant of the United States Geological Survey at St. Louis. Comparisons were made of the amounts of impurities contained in the samples taken by these two methods, and certain conclusions were provisionally reached.

At the close of the year 1904 the writer ceased to be connected with the Fuel-Testing Plant, but the work was continued on about the same lines and samples were taken in the same manner as in the previous year. A larger number of samples were tested, however, and more care was exercised in their selection and treatment than was possible during the Exposition, and consequently the results are regarded as more reliable than those obtained during the previous year. The results obtained in 1905 are now available,[2] and, together with those obtained dur-

[1] "The Commercial Value of Coal-Mine Sampling," *Trans. Am. Inst. Min. Eng.*, Vol. XXXVI., pp. 341–353.

[2] Preliminary Report of the Operations of the Fuel-Testing Plant of the United States Geological Survey at St. Louis, Mo., 1905; U. S. Geological Survey Bull., 290.

ing the previous year, they constitute a large mass of data upon which it seems possible to base final conclusions. The object of the present paper is to present a brief résumé of these results and to compare them with the provisional conclusions which the writer published a year ago.

MOISTURE.

The provisional conclusions regarding the variations in the amount of moisture in car and mine samples, based on the work of 1904 were as follows:

"The gains in the amount of moisture in the coal are about equally balanced. In the entire lot of 50 samples, 26 show a gain of moisture in the average of the car analyses and the average amount of gain expressed in per cent. is 1.35. In 24 cases there was an excess of moisture in the mine sample over the car sample, and the average percentage of excess was 1.11. Thus, considered as a whole, there was no perceptible gain or loss of moisture in transit or in the car samples as compared with the mine samples."

Nothwithstanding this apparent balance of the amount of moisture in the two classes of samples, certain differences were noted as follows:

1. "Lignites and lignitic coals are apt to show a greater percentage of moisture in the car sample than in the mine sample, but the amount of gain is small."

2. "Bituminous coals, having a high moisture content, (more than 5 per cent.), are apt to show less moisture in the car sample than in the mine sample, and the amount of loss is about 1.5 per cent."

3. "Bituminous and semibituminous coals with a small moisture content (less than 5 per cent.), generally show a gain in moisture in the car sample of about 1.5 per cent."

When the analyses made during 1905 are combined with those made during the year previous, the differences noted above disappear to a great extent. The figures showing the amount of moisture in the mine and car samples for the two years vary considerably. In some cases the former is in excess while in

others the reverse is the case. There does not appear to be any definite law governing the variation in the amount of moisture in the two classes of samples, but taken in a broad way the analyses fall into large groups which seem to be well enough marked to deserve consideration. In the previous work the only distinctions observed were in those having less than 5 per cent. moisture in the car sample and those having more than 5 per cent. In the larger number of analyses, this difference is not noticeable, but, as stated above, it is possible to divide the results into four great groups which have certain but different relations in their moisture content, as follows:

Group A.—This group includes all coals in which the average moisture content of the car sample is less than 3 per cent. Of this group 18 samples show an excess of moisture in the coal from the mines and 6 samples show an excess in the coal from the car. The total excess in the mine samples is 9.47 per cent. and in the car samples 5.48 per cent. The difference is 3.99 per cent. This divided by 24, the total number of samples, gives an average excess in the mine sample of 0.17 per cent.

Group B.—In this group are included all samples having an average moisture content in the commercial coal of from 3 to 8 per cent. Of this group 18 samples show an excess of moisture in the commercial coal and the other 18 samples show an excess in the coal from the mine. The number of samples are the same in both cases, but the total amounts are quite different, the excess in the car samples being 24.60 and in the mine samples 10.23 per cent. The difference between these amounts, or 14.37, divided by 36, the total number of samples, gives .40 per cent. as the average excess in the car samples.

Group C.—This group includes all samples having a moisture content in the average car sample of from 8 to 10 per cent. Of this group 4 samples show an excess in the commercial coal and 11 samples an excess in coal from the mine. The total amount of excess in the car samples is 2.24 per cent., and in the mine samples 10.69 per cent. The difference, 8.45 per cent., divided by 23, the number of samples, gives an average excess in the mine sample of .56 per cent.

Group D.—This group includes all samples having a greater amount of moisture in the car sample than 10 per cent. The mine samples show an excess in moisture over the car samples as in the previous group, but the excuse for considering it separately is that the average amount of excess is much greater than that of the preceding group.

Of group D, 8 samples show an excess in coal from the car, and 22 samples show an excess in coal direct from the mine. The total excess in the former case is 10.50 per cent. and in the latter 48.56 per cent., the difference, 38.06 per cent. divided by 30, the number of samples, give 1.27 per cent. as the average excess in the mine samples.

Tabulated, the results are as follows:

TABLE OF COAL GROUPS ARRANGED ACCORDING TO THE EXCESS OF MOISTURE IN MINE AND CAR SAMPLES.

Groups of Coal.	Excess in Mine Samples; Per Cent.	Excess in Car Samples; Per Cent.
A. Coals having less than 3 per cent. in car samples	.17	
B. Coals having from 3 to 8 per cent. in car samples	—	.40
C. Coals having from 8 to 10 per cent. in car samples	.56	
D. Coals having over 10 per cent. in car samples	1.27	

The meaning of the above-described groups is not well understood, especially the reason why an intermediate group B, should show an excess of moisture in the car samples when coals of both larger and smaller content show less moisture in the car lot than in the mine samples. The reasons for groups C and D are evident. They include coals having a high moisture content, and it is only reasonable to suppose that coal, of this character would lose some of its moisture in transit, especially when the shipment occurred in midsummer, as was the case with most of these samples. It is possible that the coals of class B were shipped in bad weather and hence gained moisture in transit, or it may be possible that coals of this intermediate grade are in such a condition that they will absorb moisture from the atmos-

phere more readily than those having either a higher or lower moisture content. It is possible also that group B is not a natural group, but merely due to fortuitous circumstances. If that is the case, a larger series of tests would probably show that no such group exists. The apparent disagreement with the groups recognized in 1904 seems to indicate that many of the variations are due to conditions not inherent in the coal itself, and hence are irregular in their occurrence.

SULPHUR.

In general the results of the first year showed that the percentage of sulphur in the car samples was greater than that in the mine samples, and the result was stated thus:

"The general average of the sulphur in all analyses shows an excess in the car sample above that contained in the mine sample. The coefficient of increase in the 50 samples at hand is 1.04; therefore, in mine sampling, for the purpose of determining the probable amount of sulphur in the commercial output of the mine, it is necessary to multiply the amount of sulphur in the mine sample by this coefficient of 1.04."

The results obtained during the second year serve to confirm in great measure the conclusions stated above. Of the 105 samples analyzed during the two years, 75 show an excess of sulphur in the commercial coal; 28 show an excess in coal direct from the mines; and 2 show an equal amount in each. The total excess in car samples is 261.67 per cent. and in mine samples 246.25 per cent.; 261.67 divided by 246.25 equals 1.06, the coefficient of excess of sulphur in the car samples over the mine samples. If, therefore, the amount of sulphur shown in any analysis of coal direct from the mines be multiplied by 1.06, the result will be approximately the amount of sulphur that may be expected in commercial coal from the same mines. In the report for 1904 this coefficient was given as 1.04 on a basis of 50 samples analyzed, but the additional samples tested during 1905 have given it a slightly larger amount and probably greater value.

ASH.

The relation of the percentages of ash in the two classes of samples analyzed in 1904 was found to be far more constant than either the moisture or the sulphur. "Of the 50 analyses compared, 46 show a greater amount of ash and 4 show a smaller amount of ash in the car sample than in the mine sample." The total percentage of ash in the car samples (545.35) divided by the total percentage for the mine samples (418.36) gave 1.3 as the coefficient of increase; "if, therefore, the amount of ash in any given mine sample be multiplied by this coefficient (1.3), the result will be approximately the amount of ash that may be expected in the commercial output of the mine."

The results of the combined work of 1904 and 1905 show the same regularity in excess of ash in the mine samples as was noted in the previous paper.

The total excess in the car samples is 1,062.66, and in the mine samples 825.95 per cent.; 1,062.66 divided by 825.95 equals 1.29. This may be called the coefficient of increase and can be used in converting the ash in analyses of mine samples into analyses of commercial coal; thus, if the ash in the analysis of the mine sample be multiplied by the coefficient, 1.29, the result will be approximately the amount of ash that may be expected in commercial coal from the same mine.

The coefficient determined in 1904 is 1.3, which is practically the same as 1.29, the coefficient determined by the results of 1904 and 1905. The agreement is remarkably close and certainly shows that careful sampling, even by different persons, will give approximately the same results.

Personal Equation.—As noted in the previous report, the personal element of the collectors enters largely into the results obtained; thus during the two years A collected 34 samples, and the ash in the car samples obtained by him exceeds the ash in his mine samples by an average of 2.17 per cent., whereas the average excess for the whole, 105 samples, is 1,062.66 minus 825.95 equals 236.71, divided by 105 equals 2.25 per cent. In 1904 the average for this collector was 2.4 per cent. The reduction in the average amount of excess shows that in 1905 the

sampling by this man was more accurately done; that is, more of the impurities were included in the mine sample and it was more nearly typical of the commercial output of the mines than was the case in his sampling of 1904.

B collected a total of 40 samples, and the ash in his car samples exceeded the ash in his mine samples by 2.77 per cent. In 1904 his average was 3.49 per cent. Therefore, he made a decided improvement in approximating commercial coal in his mine work. In 1904 his mine samples were entirely too clean to be representative, but the average for the two years was fair, although still above the average excess (2.25) for the whole.

C collected 12 samples and the ash in his car samples exceeded the ash in his mine samples by 2 per cent. In 1904 his average excess was 1.66 per cent.; therefore, his work in 1905 was not quite so good as it was in 1904.

D collected 3 samples and his average excess in the car samples was only .79 per cent.

E collected 8 samples and the ash in his car samples exceeded the ash in his mine samples by an average of 1.58 per cent.

D and E made the best sampling record in approximating commercial coal.

F collected 3 samples, but his work was of an entirely different character from that of any other collector, as in 2 cases out of 3 his mine samples contained more impurities than the carload lots which he shipped to St. Louis. The ash in his car samples fell below the ash in his mine samples by 2.13 per cent. There is nothing in the report to explain this anomaly, and so it must be attributed to accident or to his personal opinion as to what constituted commercial coal from those mines.

As stated in the previous paper the object of this mine sampling was to secure coal representative of the commercial output of the mine, but this was not accomplished. After a year's experience the excesses were reduced, but not to a very great extent and it is very doubtful if under this plan it is possible to secure the same grade of coal as reaches the market. There are several reasons for this which under present conditions can not well be changed.

Summed up and tabulated the results are as follows:

TABLE SHOWING RELATIVE AMOUNTS OF ASH IN CAR AND MINE SAMPLES OF THE DIFFERENT COLLECTORS.

Collector.	Work of 1904.			Work of 1904–5.		
	Number of Samples.	Average Excess in Car Samples.	Average Excess in Mine Samples.	Number of Samples.	Average Excess in Car Samples.	Average Excess in Mine Samples.
A.....	23	2.40	.....	34	2.17	.....
B.....	16	3.49	.....	40	2.77	.....
C.....	8	1.66	.....	12	2.00	.....
D.....	3	.79	.....	3	.79	.....
E.....	.....	.....	.....	8	1.58	.....
F.....	.....	.....	.....	3	.....	2.13
Av. Excess	.....	2 54	.....	.....	2.25	.....

Perhaps the most important is that the consumers do not demand clean coal and consequently the operator makes little or no attempt to keep his coal free from shale and bone during the process of mining and loading. In the second place, even if the operator is willing and anxious to improve the output of his mine, the carelessness and indifference of the miners will not permit him to do so. Positive instructions may be issued to throw out certain partings, but unless pickers are employed and suitable machinery installed, the chances are about 10 to 1 that all the partings are loaded with the coal and also a large percentage of dirt from roof or floor.

In view of this seeming impossibility of approximating commercial coal, the writer has recommended an arbitrary system of sampling which would reduce to the minimum the effect of the personal equation of the sampler and also obviate the necessity of trying to imitate the miner who not only leaves in the natural impurities of the coal, but through his carelessness adds more from an outside source. This can be done only by adopting regulations covering each step of the operation. A method of coal-mine sampling was recommended in a previous paper, which will be repeated here with such changes as have been suggested by recent work. All geologists and mining engineers are urgently requested to conform to this proposed method so that the results of analyses may be compared. At present this

is generally impossible since no information is given as to the method of sampling or of analysis.

PROPOSED METHOD OF MINE-SAMPLING.

1. Never accept weathered coal, but select a fresh face of coal at the point where the sample is to be obtained, and clean it of all powder-stains and other impurities.

2. Spread a piece of oil-cloth or rubber-cloth upon the floor so as to catch the particles of coal as they are cut and to keep out impurities and excessive moisture where the floor is wet. Such a cloth should be about 1½ by 2 yards in size and spread so as to catch all the material composing the sample.

3. Cut a channel perpendicularly across the face of the coal bed from roof to floor, with the exceptions noted in paragraph 3 and of such a size as to yield at least 5 pounds of coal per foot of thickness of coal bed; that is, 5 pounds for a bed 1 foot thick, 10 pounds for a bed 2 feet thick, 20 pounds for a bed 4 feet thick, et cetera.

4. All material encountered in such a cut should be included in the sample, except partings or binders more than ⅜ inch in thickness and lenses or concretions of sulphur or other impurities greater than 2 inches in maximum diameter and ½ inch in thickness.

5. If the sample is wet it should be taken out of the mine and dried until all sensible moisture has been driven off.

6. If the coal is not visibly moist, it should be pulverized and quartered down inside the mine to avoid changes in moisture which take place rapidly when fine coal is exposed to different atmospheric conditions. The coal should be pulverized until it will pass through a sieve with ½ inch mesh, and then, after thorough mixing, it should be divided into quarters and opposite quarters rejected. The operation of mixing and quartering should be repeated until the desired size of sample is obtained. When the work has been properly done a quart sample is sufficient to send for chemical analysis. This should be sealed in either a glass jar or a screw-top can with adhesive tape over the joint, and sent to the chemical laboratory for analysis.

7. The analysis of such a sample will show the grade of coal that may be obtained by careful mining and picking. In a majority of cases the sulphur and ash in the commercial output of the mine will exceed the amount shown by the analysis, but the former can be approximated from the latter by multiplying by the coefficients given above: 1.06 for sulphur and 1.29 for ash. These coefficients will only hold for general results, but it seems probable, that when more detailed work of this character has been done, specific coefficients may be determined for each field or for each important coal bed.

8. Each sample should be accompanied by a complete description stating definitely how the sample was obtained and what it represents so that the reader may judge for himself of its value, and when analyses are recalculated the coefficients of increase should be given together with the authority for their use or the data upon which they were determined.

9. In publishing analyses, full descriptions should be given as noted above, together with the name of the collector, date of collection, name of analyst, and care of sample after it was collected.

DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, South Bethlehem, Penna. The full name of the author should be attached to all communications.

HOW SHOULD FAULTS BE NAMED AND CLASSIFIED?

Sir:—There is one discussion of faults to which Ransome in his recent paper has not referred, which defines very clearly a fault and its parts. This is by Willis,[1] and he clearly recognizes the incompleteness of ordinary definitions limited to "normal" and "reversed." He says "the term fault is of general application to any dislocation of rocks involving movement of the separated masses past one another." He subdivides "thrusts"—dislocations due to compression—into shear-thrusts, break-thrusts, stretch-thrusts and erosion-thrusts. Willis is exceptionally careful in his definitions of the parts of a fault; and every student of the subject would do well to give attention to his diagram, which applies as well to any other type of slip as to the overthrust figured. "Throw" is defined as vertical displacement, and is distinct from "Displacement" which is the distance of separation on the fault surface. This distinction has been confused by Spurr in his text-book,[2] and is an important one, for the vertical measure of the dislocation is of consequence in triangulating

[1] "The Mechanics of Appalachian Structure," by Bailey Willis. U. S. Geological Survey, Thirteenth Annual Report, 1891–92. Part II., p. 222, and diagram opposite p. 226.

[2] "Geology Applied to Mining," New York, 1904. "Throw may be defined as the distance between the two parts of any body, measured along the fault plane."

thicknesses, whatever may have been the direction of motion, up, down or sidewise. Willis speaks of "vertical throw" and "horizontal throw" as synonymous with throw and heave, but these latter words would seem to be sufficient. They express the vertical and horizontal departure from each other of two earth particles originally contiguous, whatever path they may have followed in reaching the ultimate position of displacement.

Dr. Ransome has called attention to an important query in geological nomenclature, particularly as the nomenclature is

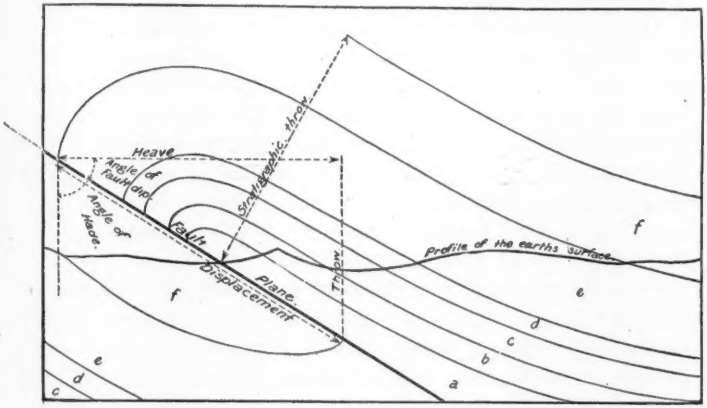

FIG. 7. Diagram of a thrust-fault or thrust. (After Willis.)

intrinsically meaningless. Downslips are no more "normal" than thrusts: the latter do not "reverse" anything: and "heave" for a lateral movement is an inexpressive term and a bad one if it is going to be confused with the mathematical "heave" above recommended. There are classes of movement not mentioned by Ransome which must be allowed for in any classification: these may be described as horizontal sliding, igneous lift, and pivotal adjustment.

Horizontal sliding may be assumed where the fault plane is essentially horizontal: it may be an erosion overthrust, or a movement of lower rocks differential to a separate horizontal series above. Such a movement must always occur where isoclinals be-

low an unconformity are extended laterally by many dikes: the surface of unconformity is then transformed into a horizontal fault-plane. This is shown at the base of the Cambrian near Deadwood, S. D., where the old erosion surface of upturned schist has been extended areally by hundreds of Tertiary dikes. The intrusives swelled vertically into sills and laccoliths in the Cambrian. The Paleozoic beds consequently remained unbroken in many places where the Algonkian beneath was forced to expand. Hence *horizontal faulting* took place along the contact between the formations.[1]

Igneous lift occurs where an intrusive body beneath raises a block of strata, so that displacement takes place along some of the bounding surfaces of the block. This kind of faulting is inevitable in a region of sills and loccoliths.[2] It is interesting by way of contrast with ordinary gravity faults and thrusts, in that the movement may be a direct upward push from below. If the fault plane be nearly vertical, its hade may be in either direction with reference to the block upraised, so as to simulate either "normal" or "reversed" faulting.

Pivotal adjustment of earth blocks is probably the commonest kind of faulting. It is that motion which would result from the tilting and pivoting of sinking blocks jostling against each other in a general process of crustal extension. Tilting of earth blocks in a single direction is common, as in the Newark formation. In the preliminary report on the San Francisco earthquake, cited by Ransome, it is further stated that "besides the general horizontal displacement of about ten feet, there is observable a differential vertical movement not exceeding four feet, whereby the southwest side of the rift was raised."

This diminishes southward to zero and "still farther south there are suggestions that this movement (vertical) may have been in the reverse direction."[3]

This last statement is very suggestive of a pivotal movement

[1] "Laccoliths of the Black Hills," U. S. Geological Survey, Twenty-first Annual Report, Part III., p. 201, Fig. 69.

[2] *Loc. cit.*, Pls. XX., XXI., Fig. 82, Pls. XLIV., XLVII.

[3] Preliminary Report of the State Earthquake Investigation Commission, California, 1906, p. 11.

of a mountain block. With a deep rotation axis S. W.–N. E., at right angles to the long rift, the movement over the axial line at the surface would be essentially horizontal, while the vertical element would be more pronounced on receding from the epi-axial point. Moreover it would be in opposite directions N. W. and S. E. of that point.[1] It is obvious that a truly pivotal motion on a fault plane would produce concentric striation. The curvature of striæ at the point of observation is a direct measure of the radial distance to the pivotal axis. In those cases where that axis is at the base of the earth-block which has moved, a computation of the length of the radius will give the vertical dimension of the block. Slickensides are ordinarily seen on such a small scale that curvature is not suspected.

"Normal" or downslip faults may be very common in a region of compression and thrust, and vice versa. But the two kinds will not be of the same order of magnitude. The one may be a secondary effect of the other and on a smaller scale. In a region of downsinking of large crustal blocks by normal faulting or pivotal adjustment, synclinoria may form in single blocks which will compress formations contained in the axial region and so generate thrusts. On the other hand, the axial region of every anticline of compression tends to split open, in other words exhibits tension, and formations within the larger anticlinal movement may slip "normally" where this tension is exerted. Hence it is always essential to an understanding of faults that the magnitude of the rock unit involved be taken into account. Faults like the San Andreas rift 300 miles long are not in the same class with slickensided surfaces in a given quartzite or diorite in a mine. The one involves an arc of the earth's shell, the other a wrinkle in a mountain range.

The questions in the last paragraph of Ransome's paper would seem best answered by agreeing to restrict the terms "normal" and "reversed" to a purely geometrical result of faulting, irre-

[1] Illustrated by placing a pencil at right angles to the wall, against the wall, on a table, and then supporting a thick book on end on the pencil and with its cover against the wall. Tilt the book on the pencil as an axis, and observe the upper edge of the book. The contact surface of book and wall represents the fault plane.

spective of genesis. The determination of genesis may be a matter of opinion. The facts of occurrence are facts, and terms must be preserved whereby to describe them. Movements on the fault plane may have changed direction from time to time, so that, as Ransome points out, the slickensides preserve the record of only the latest movement. In such case the path of an earth particle during faulting may have been devious. The result discovered in mine or ledge or quarry still requires description, and the measured throw and heave are, with reference to the normal or reversed *position* of the beds, the essential features of fault diagnosis.

T. A. JAGGAR, JR.

DO THE GEOLOGICAL RELATIONS OF ORE DEPOSITS JUSTIFY THE RETENTION OF THE LAW OF THE APEX?

Sir:—The subject of the extralateral feature of the United States mining law is one of perennial interest and the recent discussion thereon in ECONOMIC GEOLOGY is valuable; for it is always in order to examine whether legal principles are in harmony with existing industrial or other conditions to which they apply. If they are found not to be so, either from original imperfection or change of the conditions, they should be altered to conform to the best interests of the political entity, by and for which they are enacted and enforced, or such part thereof as may be directly affected.

In the present instance, however, if we wish the discussion to be of practical benefit and have influence with our law-making power (by which alone the law can be altered or repealed), we must not leave out of consideration the fact that, at the present time the real question for discussion is, whether a change is *now* advisable, taking into account the facts that the law of extralateral right, has been in force as a United States statute over forty years and for many years previous as a part of the miners rules and customs; that all metal mining (except iron) in the western states is carried on thereunder and that no extralateral right acquired during that period could be abro-

gated by any change but must continue to exist according to the law at the time of the initiation thereof.

The question as to whether, if a mining law were now proposed which was to go into effect in an early stage of mining development, the extralateral feature would be advisable, in the light of our present state of knowledge of ore deposits; or the exact question under discussion in ECONOMIC GEOLOGY,—"Do the geological relations of ore deposits justify the retention of the law of the apex?", are of theoretical and academic rather than practical interest; for such conditions have forever passed, and can never again occur in the United States. The law-making power can only consider existing conditions and the effect thereon of proposed alterations of the law; for neither Congress nor any power in the universe can reverse the succession of events and cause to exist again past conditions and circumstances.

Let us, however, consider first the historic and the geologic or scientific phases of the question. It is well known that previous to 1866 the greater part of the metal mining of the world, aside from placer and iron deposits, had been upon typical veins. This was especially true of the mining regions around Freiberg, in Germany and of Cornwall, in England, which had been the training schools of the majority of the practical mine managers of the world previous to that time. The same was largely true of the silver deposits of Mexico and Peru which were about all of the subterranean metallic deposits, extensively worked in America prior to the California discoveries. The experience of the quartz miners in California and Nevada had been the same. It was the gold or silver bearing vein, lode, lead or ledge they sought and followed downward on its course whether this was inclined or vertical. It is worthy of especial notice that in Germany, England, Mexico and California, the result on the customs and laws of the miners was the same. In one way or another, as I have shown,[1] these gave the right to follow the vein on the dip, without reference to surface boundaries. There was perhaps no time or place in the world's history when abstract considerations or unmeaning custom had

[1] Shamel, Mining, Mineral and Geological Law, Ch. 6.

less influence on men than in the days of the California gold fever. It was a "fierce democracy" guided solely by what was considered right and just under the circumstances and conditions as they knew them. The rules and regulations of these mining districts, as the very complete collection by Clarence King for the tenth census shows, in all those districts concerned with subterranean or quartz mining always gave the right to follow the vein on the dip.[1]

It is inconceivable that in all these different countries the rule of allowing the vein to be followed on the dip without reference to surface boundaries should have been developed and exercised if it was unjust or not the best possible rule for existing conditions. In the case of California, the re-enactment of the same rules in hundreds of independent mining camps by men absolutely untrammeled by any law or custom except their innate sense of justice and fair play, proves that it is simply impossible that it should have been otherwise. Consequently at the time the mining law of 1866 and the revision of 1872 were enacted, it was as perfectly adapted to the geological conditions, as then understood to exist, as any human law could be; for the congressional law was simply a re-enactment of the general features of the rules and customs of the mining districts and was desired by and had the approval of the miners themselves. Senator Stewart of Nevada, who was their spokesman, in his speech on the law of 1866[2] says: "To extend the pre-emption system applicable to agricultural lands to mines is absolutely absurd and impossible. Nature does not deposit the precious metals in rectangular form descending between vertical lines into the earth, but in veins or lodes varying from one foot to 300 feet in width, dipping from a perpendicular, from one to eighty degrees and coursing through mountains and ravines at nearly every point of the compass. . . . With such a division of a mine, one owning it at the surface and another at a greater depth, neither would be justified in expending money in cost of ma-

[1] Report Tenth Census, Vol. 14, 1880; Mining Law, Hon. Clarence King, special agent.

[2] *Cong. Globe*, First Session Thirty-ninth Congress, p. 3225.

chinery, deep shafts, and long tunnels for working of the same." Hence the sneer of the writer, whose articles will be subsequently noticed, is far from justified when he says:—"Such a piece of erroneous legislation . . . could have originated only in the brain of an individual of limited mental capacity, how such a man could obtain a hearing in a council of law-framers is difficult to imagine. . . . The law of the Apex . . . begotten in bland self-complacent ignorance by a group of opulent mechanics."[1] All Senator Stewart's contemporaries testify that he, the chief advocate of the bill and probably the proposer of the extralateral feature, was by no means an individual of "limited mental capacity," nor were his miner constituents "self-complacent" ignoramuses. And yet these were not the only men in favor of the extralateral feature of the mining law. In his report as Commissioner of Mining Statistics for 1869,[2] Rossiter W. Raymond, Ph.D., an experienced geologist and engineer who has been for many years Secretary of the American Institute of Mining Engineers, after speaking of similar rules in other countries says: "Whatever be the case in Mexico in this respect, it is, I think, quite necessary at present, in our comparatively unexplored mining region to give the miner what in early days the German law gave him, the right to follow the vein."

With practical miners and scientific experts holding the same views it is not strange that the extralateral feature was incorporated into the first U. S. Mining law. It would have been strange if it had been otherwise. The fact that Dr. Raymond afterward altered his views, as to the desirability of this feature only emphasizes more strongly the fact that in the then existing state of geological and mining knowledge the extralateral feature was in complete accordance with the best interests of mining in the light of then known conditions and features of the geology of ore deposits. It appeared to be but the dictates of plain justice, that the miner who had by his labor or the expenditure of his money, followed down a vein and developed a paying

[1] C. W. Purington, ECONOMIC GEOLOGY, Vol. I., No. 6, p. 580.

[2] Page 198, Fortieth Congress, Third Session, House of Representatives, Ex. Doc., No. 54.

mine, should be allowed to continue on his vein as far as it was profitable to work it, and not be obliged to cease operations at a boundary line and allow some one else to enjoy the fruits of his discovery and enterprise " without money and without price."

This being true in 1866 the next question is, have conditions changed since, so that what was once desirable in mining law is no longer so? Of course geological conditions have not changed. They are the same now as in 1866 and for ages before. All that has changed is our knowledge of such things. Forty years of mining and scientific investigation have brought to light forms of ore deposits formerly unknown, so that the simple classification that answered in 1866 no longer adequately represents the present state of our knowledge. It must be admitted that some of these are widely different from the conception of a typical vein or lobe.

As to a typical vein it is admitted that the extralateral law is the most equitable that could be devised, but it is urged that when applied to the more complicated forms of ore bodies that it is the cause of unnecessary litigation.

It may be noted in the first place, that according to the latest views and classification, all these more complicated and legally troublesome forms of ore bodies have a common origin with typical fissure veins. They are all subterranean deposits from aqueous solution of the metals except those arising directly by crystallization and segregation from fusion, a group which is very rare, so that the law has given the same rights on deposits which are genetically related and in this at least, is in harmony with the latest conclusions of economic geology.

The following gives the views of a mining engineer of experience of the effect of the extralateral law of mining: " Personal experience in my practice which covers a period of over 30 years during which time I have been in close touch with some of the heaviest operations in the state [Montana] with hundreds of smaller concerns and with thousands of individual miners, has convinced me that the extralateral privilege is a powerful incentive to the development of our mineral resources. . . . Personally I do not know, but if I have read aright, the pros-

pector and small operator, as we know him, is almost unknown in regions where extralateral rights are denied; and I believe that capital in contemplating development work, unconsciously pays tribute for the extralateral privileges carried by our mining laws."[1]

This quite moderate statement of benefits aroused, however, the righteous indignation of another prominent mining engineer who proceeds to argue the question as follows:[2]

"With some apologies to geometry, however, and granting that the learning of the gentlemen from Montana is as ponderous as Mr. Harper has proclaimed, it becomes apparent that here a stupendous intelligence is revealed. The men of Butte, standing on the heights, look to the north, to the west, 'beyond the utmost bounds of human thought' and, lo! the secrets of the earth are uncovered! Ledge follows ledge in bewildering succession, each coursing laterally and dipping gracefully upon its fairly uniform angle, until even the seer of Butte, with his trusty stope sheet in his hand, falls back appalled at the immensity of the spectacle. A race of giants is among us, a sapient host, whose contribution to human knowledge it is perhaps not too late to recognize. He is to enlarge the Hall of Fame, and multiply the pedestals to receive the graven forms of the deep browed sages of Silver Bow, in order that future generations may pace the stately corridors and contemplate the monuments erected by a grateful people to the ledge finders of old. . . . What ineffable wisdom is displayed by a government which permits the perpetuation upon its statute books of a law resulting from the nebulous perplexities of a council of day-laborers and village chiefs regarding the occurrence of ore deposits. . . . Are we in America—I ask it in all seriousness—to forever remain the victims of the deification of the peasant and mechanic, the hewer of wood and the drawer of water? Are we to continue to accept as truth and rules of conduct the ephemeral ravings of an enriched, illiterate proletariat? What is the law of extralateral rights but the misbegotten conception of untutored

[1] *E. and M. Jour.*, Vol. 29, p. 463, Joseph W. Harper.
[2] Chester W. Purington, *E. and M. Journal*, Vol. 29, 622.

laborers, assisted by provencial pettifoggers, who set at defiance and banish from consideration alike, physical and chemical principles controlling the deposition of ores and the precedent of centuries of the world's previous mining experiences?"

In another article[1] Mr. Purington, takes up the subject, and after relieving his feeling by the language we have quoted, on page 60 about the mental capacity of the authors of the law, gets down to specific instances of alleged injustice in the operation of the extralateral law, his first example being as follows:

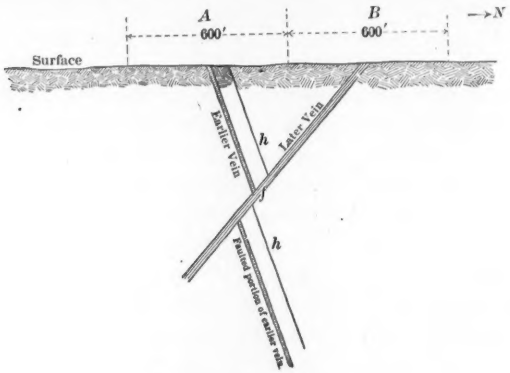

FIG. 7. (After Purington.)

(*a*) In Fig. 7 (here reproduced) is illustrated a case where one set of veins has been formed earlier in the geological history of the country than another set. Mr. A has commenced mining on his vein which is of the earlier origin and which dips north. Mr. B has located and commenced operations on his vein, a later vein, which dips south. A has stoped his ore down to the point *f* where he finds that it is apparently cut off and unites with the larger south-dipping vein. He knows that B's location is prior to his own, litigation ensues with the final result that A sinks on the foot wall of B's vein and mistaking the small stringer *h* for the continuation of his vein is beaten, although later when B has passed this point in working his prior vein, the

[1] ECONOMIC GEOLOGY, Vol. 1, 572.

real condition is revealed and A can proceed on the vein, but Mr. Purington fears that by this time he is "dead and buried or too poor."

Poor A's misfortune arose, not from the law, which could not point out the distance he would have to sink before he could again find his vein, but from the fact that he did not employ a competent geologist, who, if the conditions were as represented in the figure, ought to have recognized the stringer and identifying it with its surface outcrop, would have promptly told A that if he would sink the same distance (with a proper allowance for the angle of the fault) below the faulted stringer he would have found his faulted vein.

What would have been the result if there had been no law of extralateral rights? A, when he reached B's vein would have

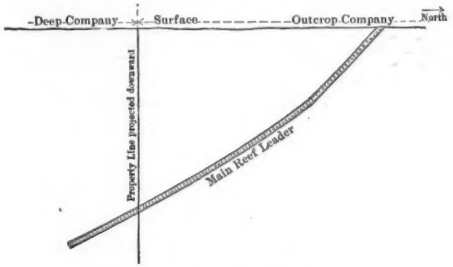

FIG. 8. (After Purington.)

taken it downward, until it reached A's farther boundary, and upward until he reached the boundary between A and B; also the further continuation of A's vein until it reached the same boundary. All that would remain to B, would be A's vein after it crossed into B's territory. This would be for A most advantageous but B would be much worse off than A was under the law of extralateral rights; so that in this instance, the law of extralateral rights causes less injustice than its only alternative.

For his next example of supposed detrimental operation of the extralateral law he leaves its jurisdiction and goes to Africa as follows:

"Fig. 8 illustrates a section on the South African Rand where all claims are bounded by vertical lines. The main reef leader is a vein representing filled interstitial space in a bed of conglomerate, interbedded with other sedimentaries, more or less auriferous. The line *a a* represents the boundary between the property of an Outcrop Company and that of a "Deep Level Company." The Outcrop Company may follow the ore down until the reef intersects this imaginary line and no farther. The Deep Level Company may extract ore from this same reef southward from this line to its south side line and no farther. A further set of companies called the "Deep Deep" Companies or second set of deeps has been formed to exploit the main and other conformable reefs still to the south of the Deep Level Companies' ground. Mr. Hennen Jennings stated in 1903 that some fifty-three [deep] level companies had been formed, fourteen of which had reached the producing stage. In the case of all of them, it was necessary to sink shafts from one thousand to two thousand feet in depth in order to reach the veins, and eighty-one shafts with an aggregate depth of 88,405 feet of depth had been sunk for this purpose; of these fifty had intersected the reef. Besides the enormous expenditure which these shafts represented before a pound of ore could be extracted the various financial houses estimated a further expenditure of $252,000,000 in connection with the deep levels and other projected improvements. . . .

What would have been the case of the law if the apex had existed in South Africa? Not one company of the first or second deeps would have been formed, and not one dollar would have been expended for the legitimate exploitation of the ore in depth excepting by the companies owning the outcrop of the veins or reefs as they are called.

Numerous dikes of greenstone cut and fault the reefs, for the most part dipping much more steeply than do the reefs themselves. Some of these dikes are accompanied by auriferous veins, not payable. Under the conditions of the apex law, some energetic individual with more astuteness than integrity would have inevitably sunk on one of these veins claiming this or that as pay ore until he intersected a bona fide payable reef, which he

would endeavor to lay claim to as the continuation of his vein downward, while his own 'apex' might lie hundred of feet to the south of the actual outcrop of the reef. Lawsuits would be common. Serious capital would be shy of investment under such conditions."

It seems that in this example that even "an individual of limited mental capacity" ought to see that the operation of the extralateral law would have been better for all concerned. Even if some one with "more astuteness that integrity" had, as he supposes, sunk on an auriferous vein accompanying the greenstone dike and had attempted to claim the conglomerate reef, a lawsuit at the expense of a few thousand dollars would have finally disposed of such attempts, and the expenditure of $252,000,000 in addition to the enormous cost of eighty-one,

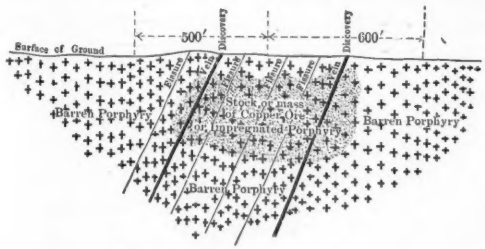

FIG. 9. (After Purington.)

probably mostly unnecessary, shafts would have largely been saved for, under the extralateral law the ore could all have been removed through the outcrop shafts. Of course it might have been more economical to have removed some of the ore by shafts farther back than the outcrop shafts but no such number would have been constructed as under the vertical boundary rule that controls on the Rand.

But it is doubtful if even one lawsuit would have been necessary, because if the extralateral law was in force on the Rand, the outcrops of the reefs being located first and hence prior would have taken the whole vein beyond the place of union, so that such a suit would never get past a demurrer.

His other examples are shown in figures 9 and 10. In Fig. 9 a "great spheroidal body of coper ore" has two outcrops located by different men. The situation in Fig. 9, might present some difficulty, but would doubtless be solved with entire justice to all concerned by the courts. Such shaped deposits are infrequent and the condition shown in the figure of two veins, rising from such a deposit and these reaching the surface at such distances apart that they would be liable to outcrop in different mining locations is immensely more rare. They do not occur in sufficient numbers to form a reasonable "exception" to the general rule.

Statutes and ordinary rules of law can only be constructed to meet conditions that occur in a reasonably general and frequent manner. Infrequent and exceptional occurrences must be left to be dealt with by the courts when they arise and, to their credit, they are usually equal to the emergency and decide them justly.

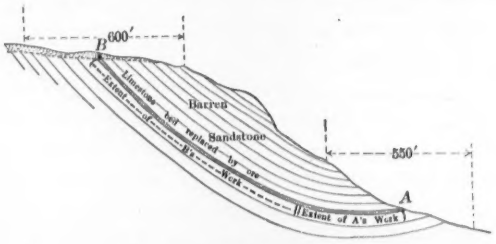

FIG. 10. (After Purington.)

In Fig. 10 a silver impregnated limestone bed outcrops twice and locations are made on both outcrops. A quite diligent reading of practically all the mining decisions in the United States has not disclosed any such situations in any litigation that has reached the higher courts. Mr. Purington states that the figures represent actual ore deposits, but as he does not state otherwise, we must presume that the statements as to discovery marking and litigation are hypothetical. As to the situation disclosed by Fig. 10, an inspection shows, that under the rule of only mining to the vertical planes through the boundaries, neither A nor B would

get as much as Mr. Purington allows them in his figure under the extralateral law, and so would be worse off than under it. But it is to be noted further that under the definition of apex, as stated by the courts with reference to mining law, it is highly improbable that A would be regarded as having a legal apex necessary to extralateral rights on the vein or deposit although he was located on an outcrop. As in the celebrated case of Duggan *vs.* Davy[1] it would, in all probability, be decided that the exposure was one on the dip of the vein which gives no extralateral rights.[2]

Consequently A would be incapable of depriving B of the "hardly won" fruits of his labor as feared by Mr. Purington.

These are the worst instances that the "fiercest" critic of the extralateral feature of the mining law is able to cite, and, when analyzed; it turns out that even in these the preponderance is strongly in favor of the extralateral law doing justice rather than its only alternative,—the so-called common law rule of subsurface rights limited by vertical planes through the surface boundaries. Therefore, considering the law, with reference only, to geological conditions in the light of the latest knowledge concerning the same, it appears that the extralateral law accomplishes the "greatest good for the greatest number" which is all that any law can do. It, therefore, ought not to be repealed on account of geological considerations.

In Mr. DeKalb's contribution to the discussion he seems to think that if definite walls are lacking then "the law fails precisely where protection to the most extensive interests are at stake, because in form and character, and from the absence of clearly bounding walls, our greatest veins do not in a large majority of cases conform to the geological prescription of the lawmakers." In this, however, he is mistaken for the statute says nothing about walls and the decisions of the courts say explicitly that definite walls are not necessary for a vein in order that it may carry extralateral rights. Thus in one case the court says:

[1] 4 Dak. 110, 26 N. W., 887.

[2] Iron, Silver, etc., Co. *vs.* Elgin, 118 U. S. 196; Eiler *vs.* Boatman, 3 Utah, 159; Lindley on Mines, sec. 807; Snyder on Mines, Secs. 796–797.

"Nor on the contrary is it required that well defined walls shall be developed."[1]

The United States Supreme Court in a leading case[2] on this subject says: "It is enough to say that a lode or vein is a body of mineral or mineral bearing rock within defined boundaries in the general mass of the mountain."

In this definition the elements are the body of mineral or mineral bearing rock and the boundaries; with either of these things well established, very slight evidence may be accepted as to the existence of the other. A body of mineral or mineral bearing rock in the general mass of the mountain, so far as it may continue unbroken and without interruption, may be regarded as a lode, whatever the boundaries may be. In the existence of such a body and to the extent of it boundaries are implied." In still another case[3] the court says: "It is true a lode must have boundaries but there seems to be no reason for saying they must be such as can be seen. There may be other means of determining their existence and continuance as by assay and analyses." Consequently this objection of Mr. DeKalb is unfounded.

Another geological objection made by Mr. DeKalb is the difficulty of determining the rights of "masses" with "no single top or apex, and no ascertainable dip." Such bodies, if unconnected with any vein, would come within the common law presumption that all beneath the surface belongs to the surface proprietor for this presumption controls except where the statute expressly provides otherwise. It is expressly decided in a case the reference to which I do not now have at hand, that detached ore masses belong to the owner of the surface beneath which they are found.

In the leading case of Doe *vs.* Waterloo[4] the court says: "It is entirely true that whoever takes a grant of a lode claim, takes it subject to the provision of the statute reserving to locators of

[1] Burke *vs.* McDonald, 2 Idaho, 679.
[2] Iron Silver M. Co. *vs.* Cheeman, 116 U. S. 529.
[3] Hyam *vs.* Wheeler, 29 Fed. 347.
[4] 54 Fed. 935.

other mining claims the right to follow under its surface, for the purpose of extracting the ore therefrom, of any vein, lode or ledge, the top or apex of which lies within the surface lines of such other location. But until some one comes clothed with that reserved right, the holder of a government patent or certificate has, I think, the just and legal right to say 'Hands off of any and every thing within my surface lines extended vertically downward.'" . . . Except as modified by statute, no reason is perceived why one who acquires ownership or possession of such lands should not hold them with and subject to the incidents of ownership and possession at common law."

Consequently the case of a deposit in the form of a mass without any apex would not present any serious difficulties. Not being within the extralateral statute, its ownership would be decided according to common law rules. It is no reason that the extralateral law should be repealed that this particular form of deposit does not come under its control.

The above discussion takes into account only geological considerations and conditions but, as heretofore mentioned, there is another very weighty reason against substituting another rule for that of extralateral rights, in the fact that the latter has been the law for over 40 years during which time thousands and thousands of locations have been made and many of these developed into properties of enormous value. Existing extralateral rights could not be abrogated by the enactment of a new system, but must continue to exist according to the law, at the date of making the location. Locations made after the passage of such a law would be subject to the extralateral rights of claims previously located, while the owner thereof would have no compensatory right of pursuing his vein or deposit beyond vertical planes through his boundaries.

The result would be the introduction of ten fold worse confusion than the severest critic of the extralateral law can conjure up in his imagination when under the sway of his darkest apprehensions. This fact, and the inherent justice of the principle far outweigh any possibilities of future litigation that may possibly be involved in the continuance of the extralateral law, even when

applied to the later discoveries of anomalous forms of ore deposits.

It is unquestionably true that precious metal and copper mining have been attended with a great deal of litigation, in the United States and that in a considerable part of such litigation the extralateral law has been involved, but it is not responsible for nearly all of the litigation that has afflicted mining. The truth is, that from the very nature of the industry of mining for the precious metals, involving more than most others the elements of chance; awarding to some rich prizes and to others only blasted hopes and bitter disappointments, it is peculiarly subject to bitterly fought litigation. This has been so in all countries and times. It long ago attracted the attention of the King of Spain, who in 1785, in promulgating new mining ordinances for Peru says: "The King, convinced of the deteriorated condition in which the important branch of mining of that kingdom has fallen, from a want of method in government the *Reales* of mines, and also on account of the frequent and troublesome litigations in which the individuals of this useful profession are involved, causing them enormous expenses and distraction from their business by requiring them to reside in the capital and in other places where they go in the prosecution of their lawsuit;"[1] . . . , etc.

A large part of the litigation that afflicts mining in the United States arises from questions connected with the making and marking of a location, etc., into which the extralateral law, does not enter while another large part is about the corporate organization and management. I know of an Arizona mine, which held a good position on the dividend paying list, but litigation broke out within the corporation between the three main stockholders, and has been in the courts 13 years in one form or another and is still unsettled although the mine has filled with water and is idle. There is nothing in the annals of extralateral litigation that equals the long drawn out contests about the New Jersey zinc deposits, near Franklin Furnace which in different forms was before the courts for nearly fifty years but which arose under common law principles.

A writer familiar with mining litigation in Colorado says in

[1] Halleck on Mines, p. 589.

the course of a discussion in the Engineering and Mining Journal on the extralateral law: "Also I must believe that the Doctor dictated hastily in stating that the 'extralateral' underlies 99.9 per cent. of our mining litigation. I know to a certainty that no such statement is true of the San Juan in Colorado, at least so far as the number of cases is concerned; in fact I would be inclined to almost reverse the figures. My observation is that the overwhelming number of cases are 'adverse' suits to say nothing of many suits over grubstakes, divisions of interests, trusteeships, etc."[1]

The application of the common law principle of subterranean rights bounded by vertical planes through the surface boundaries would be easier and perhaps more satisfactory in relation to some anomalous forms of ore deposits, but these are a small minority in comparison with the total number of workable deposits. The expense of settling disputes by law, about the comparatively small number of doubtful deposits, is a very much smaller detriment to the precious metal mining industry than the useless expense, losses, injustice and discouragement from development of prospects, that would result from the application of the unyielding common law principle of the surface proprietor owning everything beneath to the center of the earth.

My belief is that, on the whole, it is not advisable to repeal the extralateral features of the United States Mining law.

CHARLES H. SHAMEL.

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[1] *E. and M. Jour.*, 77–1036, W. F. Mathes.

REVIEWS

Report of the Commission appointed to investigate the zinc resources of British Columbia and the conditions affecting their exploitation. By W. R. INGALLS, PHILLIP ARGALL, A. C. GARDÈ, AND OTHERS. Mines Branch, Department of the Interior, Ottawa, 1906. Pp. 400, with numerous illustrations, including maps and colored sections.

In many particulars this report is a notable contribution to our knowledge of the zinc industry. It is also notable as an example of what may be accomplished by prompt action. The letter of instructions authorizing the work was issued to Mr. Ingalls by Dr. Eugene Haanel, Superintendent of Mines, under date of August 14, 1905. Mr. Argall, to whom charge of the field work was intrusted, left Denver for British Columbia on September 1. The samples taken for metallurgical investigation reached the laboratory by the end of the year; the report was submitted September 27, 1906, and the whole volume of 400 pages, with numerous illustrations, including maps and colored sections, was being distributed in November. This promptness stands not only in refreshing contrast with past experiences in Canada, but also with present conditions surrounding the printing of similar reports at Washington and in the various states. The simplicity of administrative machinery which permits such promptness is wholly admirable.

The investigation covered the following points:

1. Examination of the present development of the mines to determine approximately the tonnage of zinc ore immediately available, its occurrence and character and the future prospects, together with the cost of mining.

2. Examination of the present methods of milling.

3. Investigation of the adaptability of the ores to the new methods of concentration (magnetic, electrostatic, etc.).

4. Study of the conditions affecting marketing of the concentrates, including the question of smelting in the Province or elsewhere in Canada.

5. Investigation of the possibility of special utilization of the zinc ore of high silver content.

The field examination, made by Mr. Argall and Mr. Gardè, was confined to mines which had shipped zinc ore or were known to contain zinc reserves. In each case notes on location, development, milling facilities and shipments were collected. Where possible, estimates of ore reserves were made. Mr. Argall's conclusions on the latter point are summarized below.

ORE RESERVES.

Coming now to the ore reserves and output of zinc ore from the Slocan, the largest amount, partially blocked out, "being developed," in any one mine is 60,000 tons of zinc blende, concentrating ore, probably equivalent to 25,000 tons of shipping ore of 48 to 50 per cent. in zinc. Owing to the lack of development in the majority of the mines examined, any general estimate of "ore developed" or "ore being developed" would be very misleading, while the "ore expectant" under these conditions it is impossible even to guess at.

In the mines I examined, a careful comparison shows that the zinc blende will average two and one half times the weight of the galena present in the veins; figuring on the higher saving of galena in the concentrating mills, one might reasonably expect, when arrangements are completed to save the zinc blende in all the ores milled, that the output of the zinc blende will be double that of the galena; this I believe will be a safe figure, and as the mills are improved and better saving effected, the zinc blende output should approach two and one-quarter times that of the silver-lead in any given year.

The lead output depends on several matters: The permanency of the veins; whether the mines are worked throughout the year or only in the summer months; or if the present half-hearted mining methods are to give way to a vigorous leasing system.

As regards the veins, we have seen that they carry pay ore to great depths and have been but partially worked, for silver-lead ore only; that with lead and zinc as profitable minerals, the value of the veins is greatly enhanced.

Lastly, in such a densely wooded country it is very doubtful if one-half of the pay veins have yet been discovered; consequently, it is not too much to expect that the Slocan veins can be worked at a profit

for at least twenty years to come, more especially if cheaper methods of mining are adopted and mills erected that will effect a better saving of values.

The second reason I have given for the present mining torpidity in the Slocan, lack of proper facilities for making a close saving of values, I shall enlarge upon in the following chapter on milling.

Mr. Ingalls' field work consisted mainly of an examination of the metallurgical establishments of the Province, but he has also summarized and digested the entire report and made large additions from his store of general knowledge. Indeed it is not too much to say that his personal contribution, forming the first 143 pages of the report, is the best general statement now available regarding the production and demand for zinc ores in America, and the methods of milling and smelting them. While necessarily less detailed than his well-known books on these subjects, the matter is stated less technically and is now more up to date. These are important advantages to geologists, investors, and general readers, who want principles rather than details of practice. For readers in the United States supplementary matter regarding mill practice at Joplin and in Wisconsin is desirable, and more data regarding the work of the Blake and other electrostatic machines. It is a disappointment that the Blake machine was not more used in making the elaborate tests which were carried on in the well-known laboratory of Mr. Henry Woods at Denver. As it was only tried in cases where the magnetic machines failed, little was added to present knowledge regarding its work. The new data regarding the work of the Dings and International machines is welcome.

Apparently Mr. Ingalls sees a good future for the zinc mines of British Columbia, particularly if the ores can be admitted to the United States free of duty. Failing this, shipments to Europe seem on the whole more likely to be permanently profitable than local smelting. The present need is a few well equipped and well run custom retreatment mills, such as are growing up in our own western states. An interesting feature of the investigation was a short series of tests on the application to the British Columbia ores of the flotation processes developed in Australia. Encouraging results were obtained.

The most disappointing feature of the investigation is the small amount of attention devoted to geology. Indeed it is not too much to say that there seems to have been a complete lack of appreciation of the opportunities along geological lines afforded by the work. It was only as an afterthought that Dr. A. E. Barlow was employed to examine the undeveloped zinc prospects of the region, and he went to the field so late, October 7, that it was impossible to visit many of them. His report, accordingly, consists mainly of notes on localities supplemented by a review of literature. To this report is added certain data collected by correspondence with the various gold commissioners.

The actual mine descriptions by Messrs. Argall and Gardè are fairly tantalizing in their incompleteness in regard to geology, but at the same time afford alluring glimpses of excellent data evidently available. It would seem that any proper estimate of the extent and importance of the zinc resources of the Province, particularly in view of the admittedly small ore reserves developed, should first of all be based upon definite notions as to the origin and nature of the ore bodies. Whether the ores are primary or whether they represent secondary concentrations is certainly of large importance. The bottoms of particular zinc ore shoots have been found (p. 177), but there is no suggestion as to whether this is because the bottom of secondary enrichment was reached or whether the bottom of a primary ore lense had been struck. If, as some of the descriptions suggest (pp. 168, 206), secondary enrichment has occurred, a careful study of the relations to structure and topography ought to not only permit a rational guess as to permanence of ore bodies to be made but should also afford valuable hints for their development. So far as the reviewer has been able to discover the possibilities of such a line of investigation were not at all appreciated, and in fact "secondary enrichment" is nowhere discussed. This is the more surprising in view of the importance which has attached to the subject in recent years, and the delicate index to this process afforded by the relations of lead, zinc and iron sulphides.

In a few instances Mr. Argall ventures predictions as to extensions of ore bodies in depth (pp. 159, 182), but the reasons

for this belief are not stated. In the description of the Lucky Jim Mine, a " segregation of limestone " is referred to (p. 205) though it is not entirely clear why anything other than an ordinary bed of limestone interbanded with the slates need be supposed to have been present.

These criticisms of course apply to the scope of the investigation, and do not necessarily fall on the men employed in it. Indeed so much that is good has been given that much more might have been forgiven if necessary.

Incidentally some excellent work on the minerals was done by Mr. W. George Waring. He determined that the siderite was practically barren, that the silver comes from freibergite, and that the latter is most intimately associated with the galena. Just such definite data on the association of the values and the individual minerals found in particular ores is highly desirable if progress is to be made in the study of ore deposits.

H. Foster Bain.

The Petroleum Industry of Southeastern Illinois. By W. S. Blatchley. Illinois State Geological Survey, Bull. No. 2, 1906, pp. 109.

This, the second bulletin of the new Geological Survey of Illinois, has appeared with surprising promptness, considering that the field work was done as recently as last spring. As stated in the letter of transmittal, Dr. Blatchley is especially well qualified to prepare the report, in view of his familiarity with the Indiana oil fields.

The introduction opens with a brief discussion of the nature, distribution, and quality of Illinois petroleum. Then comes a brief history of the oil and gas development and an outline of the present condition of the industry in that State. Thus far the principal development has been in Clark, Cumberland, and Crawford counties, near the eastern border of the State, and the report is devoted mainly to a consideration of this territory. Eleven pages near the end of the report, written by Dr. T. E. Savage, are, however, given to a detailed description of the gas field in Pike County, on Mississippi River.

After the general outline, the petroleum producing rocks of Illinois are briefly described. All the oil is found in the Mansfield sandstone and "Lower" and "Upper Coal Measures" of the Carboniferous system, the base of which in Illinois rests on a great erosion unconformity. A very detailed section of the Carboniferous rocks is given, but its possible value to a person using the report is diminished somewhat by the omission of nearly all geologic names and correlations, only the numbers by which the coals are locally known being given. The total thicknesses in the section are also unfortunately omitted. Owing to the newness of the Survey the geologic structure of Illinois has not been worked out in detail, but in general disposition the rocks are nearly flat, being only gently folded and sometimes faulted. Six "lines of structural deformation" have been recognized and are represented on a small map. The oil occurs in Carboniferous sandstones and limestones, lying 300 to 1,100 feet below the surface.

A review of the principal theories for the origin of petroleum and gas precedes the detailed discussion of the occurrence. In discussing the "Conditions of Accumulation," Dr. Blatchley adheres closely to the rules that have been found applicable to the fields of Ohio and Indiana, without regard to what has been done in other fields. He enumerates four necessary conditions, as follows: (1) a porous stratum; (2) an impervious cover; (3) an anticlinal structure; and (4) pressure behind the oil to force it into the reservoir. The first two conditions are generally accepted as applying to all oil fields in the Paleozoic rocks, but the second is decidedly questionable as a general condition, since many oil pools are known to exist on monoclinal dips, in flat rocks, and even in the bottoms of synclines. It is true that in the Illinois field the oil may occur only on the anticlines, but experience in other fields has shown that anticlines are not essential to the accumulation of oil.

Dr. Blatchley seems to have assumed that the oil-bearing rocks of the Illinois field are saturated with water, for only on that assumption and also that the water level is at a higher level than the accumulation of oil, can the anticlinal condition apply.

Such a condition of saturation may prevail, but no facts are given to support it, and in the published records of the wells almost no mention is made of water. If the oil-bearing rocks are saturated, then the oil has been forced up the slope of the rocks to the surface of the water, or until further progress was blocked by anticlinal structure or by an impervious condition of the sand. If the rocks are dry, the oil presumably is moving slowly down the dip under the influence of gravity, and consequently pools may occur at any point on the slopes, or in case the rock is uniformly porous the oil may accumulate in the bottom of the synclinal trough. Numerous examples of such accumulations in Pennsylvania and West Virginia could be cited in proof of the statement.

In oil investigations that have been carried on within the last 10 or 15 years, very little attention has been given to the question of saturation by water, and only a little data are available on the subject. The experience of the reviewer in some of the Pennsylvania fields has led to the belief that the condition of the oil sands as regards water is a most important question and one that must be known before it is possible to determine where accumulations may occur. Reliable data on this subject are sometimes not easily obtainable; but if geologists and others interested in the solution of the oil problem would secure all possible information on this question and present it fully in their reports, the data would go far towards a solution of these problems.

The fourth condition of accumulation also may be seriously questioned as a general proposition. Dr. Blatchley states, "It is now almost universally admitted that the rock pressure in most oil fields is nothing more or less than water pressure, as in artesian wells." This theory was ably advocated by the late Dr. Edward Orton to account for the rock pressure in the Ohio field and in that case it seemed to apply, but, as stated before, in many fields the rocks are dry and hence hydrostatic pressure can have nothing to do with the case. Even where the rocks are dry, pressure in some places amounts to as much as 1,000 pounds to the square inch. On the above hypothesis we must attribute rock pressure to one thing where the rocks are saturated and to

an entirely different cause where they are dry. Since in the latter case the expansive force of the gas is the most plausible explanation, it seems probable that some of the rock pressures where rocks are saturated are due to the same cause. But whichever is correct, it is certain that the hydrostatic theory is not "almost universally admitted," and such a general statement is misleading.

The greater part of the report, comprising about 55 pages, consists of a detailed discussion of the oil fields by counties and townships. In each one of the three principal counties a discussion of the wells is preceded by a sketch of the geology, and a number of sections of the rocks are introduced. The individual wells are discussed in some detail, and numerous records are given. Like records reported by well drillers in most regions, they are extremely incomplete, only one or two good records being given. This constitutes another example, like those which are conspicuous in every report on oil and gas, showing the great need of educating well drillers up to the level where they will be capable of appreciating the value of complete and accurate records of the strata.

An interesting feature of the report consists of several analyses of well drillings from the "pay" and associated beds. By means of these analyses the best or most porous portions of the oil-bearing limestones were found to be most dolomitic.

Following the detailed discussion, ten pages are given to a brief consideration of the process of recovering petroleum from the earth in the Illinois field, describing the process of leasing and locating wells, the form of lease, cost and methods of drilling, shooting, operating, and other data valuable to a new operator and interesting to the general public. Good advice is given against burying money in fake oil companies, such as generally spring up in every new field. A list of bench marks is appended for use in development of the field, and the report closes with a discussion of the quality of Illinois petroleum by Dr. F. F. Grout.

Of course the value of all reports of this kind to parties already operating in a field is somewhat questionable, for the reason that

the detailed geologic structure and correlations of the various "sands," which are what are most needed to assist future development, can not be determined without much geologic field work based on accurate topographic maps. As a whole, however, this bulletin seems to be an excellent account of the condition of the petroleum industry in Illinois in 1906, and it will be valuable to persons at a distance desiring information regarding the field. The material is presented from the practical standpoint, the few illustrations have been well selected, and the maps especially will be valuable to prospectors and other interested parties.

F. G. CLAPP.

Notes on the Foothill Copper Belt of the Sierra Nevada. BY A. KNOPF, University of California Bulletin, Department of Geology, Vol. 4, No. 17, pp. 411–423. August, 1906.

The author describes briefly the copper deposits along the foothills of the Sierra Nevada, from the vicinity of Smartsville and Spenceville, Nevada County, through Placer County, with its at present most important mine, the Dairy Farm, down into Calaveras County, from which the mines of Campo Seco, Copperopolis, and Napoleon are described. The account makes no pretence of completeness, but brings out a number of interesting details in occurrence and mineral association. The deposits form in general replacements along shear zones in the greenstone belt of the foothills; the ore minerals are pyrite and chalcopyrite, sometimes with a little galena and zincblende, and are associated with quartz, calcite, chlorite, epidote, chalcedony, and sometimes zeolites. It is regretted that the author does not discuss questions of genesis for this well-defined group of deposits. The most striking facts are the universal connection with the sheared greenstones and the mineral association which is so entirely different from that of the gold-quartz veins. It seems to the reviewer that the conditions shown to exist point very clearly to a derivation of the copper from the greenstones and a deposition not due to thermal waters, but rather to the chemical activity during the shearing, aided by a moderate supply of rock moisture.

Incidentally the question of the proper classification of the "greenstones" comes to the front. As shown by the author, in agreement with the geologists who mapped the quadrangle of the region, these rocks are not at all uniform, but comprise, within limited spaces, diabase, old basalts, old andesites, and various pyroclastic rocks. The quartzose porphyries are usually easier to separate. It is rather doubtful whether the greenstones can be adequately described by the blanket term "meta-andesite," as proposed by Ransome.

W. LINDGREN.

An Alteration of the Coast Range Serpentine. By A. KNOPF, University of California, Bulletin, Department of Geology, Vol. 4, No. 18, pp. 425–430. May, 1906.

Large outcrops near North Berkeley are shown to consist of mingled magnesium and calcium carbonates, with chalcedony, and to have been derived from serpentine by action of solutions containing carbon dioxide, calcium carbonate, and metallic sulphides. Attention is called to the fact that similar rocks accompany the quicksilver deposits of the Coast Range in many places. The reviewer would add to this that very similar "ankerite and mariposite rocks" along certain parts of the Mother Lode in Tuolumne and other counties have undoubtedly a similar origin.

W. LINDGREN.

Ueber die Beziehungen zwischen Erzgängen und Pegmatiten. By R. BECK, Friberg, Saxony. Zeitschrift für praktische Geologie, Bd. XIV., No. 3, pp. 71–73. March, 1906.

In this short paper, originally read at Johannesburg before the British Association for the Advancement of Science, Professor Beck calls attention to the close relationship between pegmatite dikes and mineral veins. At first the tin deposits are discussed and the remarks fully justify the above statements in the case of this special class. The tourmalinic copper deposits and the gold quartz vein are then mentioned, among the latter these of Beresovsk, Telemarken, the Southern Appalachian States and the Passagem mine of Brazil. Their points of similarity with pegmatites are strongly emphasized, almost unduly so it seems to the reviewer, and the somewhat forced pleading for a special case detracts from the value of the paper. While

Hussak regards the Passagem mine as an extreme case of a pegmatite vein his excellently presented facts fail to carry conviction to many. The Yukon quartz veins cited by Spurr include as yet no actually worked deposits. In the case of the veins of the Southern States it is safe to say that no direct relationship can be traced between them and the pegmatite dikes which are so abundant in the same region. Orthoclase and albite are of very rare occurrence. Tourmaline, apatite and garnet are occasionally found, but their presence does not seem to conclusively demonstrate the point made by the author. The closing words of Professor Beck seem to indicate that he considers the presence of certain silicates in deep-seated veins sufficient reason to emphasize their consanguinity to pegmatites. To refute this it is only necessary to refer to the great abundance of adularia in tertiary veins formed close to the surface.

W. LINDGREN.

Die Eisenerzlagerstätten bei Kiruna. By O. STUTZER, Freiberg in Saxony. Zeitschrift für praktische Geologie, Bd. XIV., No. 3, March, 1906, pp. 65–71.

New observations from the wonderful deposits of magnetite at Kirunavaara and Luossavaara in the most northerly district of Sweden are always of interest and Mr. Stutzer adds many important notes to the previous investigations of Lundbohm, Bäckström, De Launay and others. The exploitation is already proceeding at the rate of one and a half million metric tons per annum and it is said on authority of Vogt that at Kirunavaara 292 million tons of probable ore are in sight down to a depth of 300 meters below the level of the lake. At Luossavaara the ore is estimated at from 500 to 750 millions of tons of which 100 millions are available by quarrying. The deposit at Kiruna forms a north-south ridge about 4 kilometers in length and rising 249 meters above the lake Luossavaara which has an elevation of 729 meters above the sea. The magnetite deposit forms the highest part of the ridge and has ordinarily a width of from 32 to 152 meters. The ore carries from 67 to 71 per cent. metallic iron and is somewhat admixed with apatite. The slopes of the ridge consist of porphyry, but some distance to

the west there is some syenite as well as schists with benches of conglomerate and overlying quartzite.

Petrographic examination of the soda-rich syenite shows principally perthite with some uralitic augite, titanite, apatite and magnetite. Much of the latter three minerals are clearly of secondary origin.

The ore body has a dip of about 55° to the east. The porphyries on the two slopes of the ridge are somewhat different; that on the western or foot-wall side is usually of greenish color and contains in a dense, fine-granular ground mass phenocrysts of perthitic feldspars and augite partly converted into hornblende. There are two generations of magnetite, the later of which is clearly an immigration partly surrounding the feldspars and entering in them along cleavage planes. The rock also contains apatite. The apparently sharp contact between ore and foot-wall porphyry shows in detail a narrow zone of transition due to small sharply defined veinlets of magnetite which enter into the porphyry. An ultimate product of this zone is a mixture of magnetite with green hornblende, and contains vugs filled with apatite, magnetite and titanite. The main part of the deposits contains no vugs. The porphyry contains 6 to 7 per cent. of soda and about 61 per cent. silica.

The reddish, hanging wall porphyry is essentially similar in microscopical character but contains much more quartz—71.30 per cent. according to the analysis of Bäckström, and has been classified as a quartz-keratophyr. It contains fragments of the iron ore and of the other porphyry and is thus later than both of these.

In some places both sides of the ore body consist of the less acidic porphyry. As stated the iron ore consists chiefly of magnetite and apatite in intimate intergrowth. Other minerals, on the whole of rare occurrence, are talc, yellow mica, dolomite, pyrite and titanite.

Many different explanations have been advanced to account for the genesis of this remarkable deposit. Högbohm, in 1898, considered it as a magmatic segregation in acidic or neutral rocks analogous to the deposit at Tavberg and others in basic

rocks. The author considers that the form of the mass, the contact zone and its demonstrated continuation in depth speak against such a hypothesis.

The geologists who first visited the deposit in 1891 believed it to be of sedimentary origin and De Launay has recently, in 1903, attempted to defend this hypothesis. He thinks that the foot-wall porphyry represented a perhaps submarine flow at the surface of which gases of chlorides and sulphides of iron developed and were oxidized to ferric oxide. A later eruption covered this deposit which was later on metamorphosed into magnetite. Mr. Stutzer combats this view effectively and then advances his own hypothesis, which is similar to that proposed by Löfstrand some years ago. It is in brief that the ore body is a dike; the rock of which is composed of magnetite and apatite, consolidated together from the molten state. Irregular masses of pure magnetite in ores richer in apatite are explained as "schlieren" in a solidifying magma. The narrow transition zone between ore and foot-wall porphyry is considered as a product of contact metamorphism. The sequence of events closed with the irruption of the acid porphyry.

W. LINDGREN.

Die Eisenerzlagerstätte Gellivare in Nordschweden. By O. STUTZER. Zeitschrift für praktische Geologie, Bd. XIV., No. 5, May, 1906, pp. 137–140.

The great iron mines of Gellivare in the northern part of Sweden produce at present about one and one-half million metric tons of ore per annum. Many investigations of this ore deposit have been undertaken, the most important since 1890 by Hj. Lundbohm, G. Löfstrand, Hj. Sjogren, A. Törnebohm and L. De Launay, but the views concerning its origin are still far apart; both the sedimentary and the epigenetic hypotheses have adherents.

Gellivare is situated north of the Arctic circle and differs considerably from the old and well-known deposits of iron ore of the central part of Sweden. The ore is principally won by open workings, and its mineralogical composition is the same as that of Kiruna, *i. e.*, magnetite and apatite. The ore is schistose,

conforming with the steep dip of the country rock and forms large lenses, partly imbricating on parallel strike lines.

The rocks are chiefly gneisses. The red gneiss is most common near the deposit and is often traversed by irregular veins of magnetite. It consists of albite with some quartz, chlorite, apatite and biotite.

The reddish-gray gneiss is similar in composition but contains also soda-lime feldspars, microperthite, augite and hornblende. Both rocks are rich in soda.

Dikes of acid rocks, locally called granite, but really a quartz-diorite or a quartz-keratophyr are cut across the ore body.

At the contacts of the ore bodies lie coarsely crystalline masses of hornblende with some irregular masses of fine-grained feldspar, which are locally called "skarn" from their similarity to the "skarn" of the central iron belt of Sweden. The latter are masses of hornblende, augite, garnet, etc., which usually lie on the contact of magnetite and limestone. These hornblende rocks are different and Mr. Stutzer believes that they correspond to the contact zone described by him from Kiruna. The ore consists of crystalline magnetite and apatite in widely varying quantitative relations. Locally appear pyrite, chalcopyrite, fluorite, calcite and zeolites.

The author believes that the deposit at Gellivare has a similar origin to that of Kiruna. Sjögren and De Launay believe in the sedimentary origin, and their views are principally based on the parallelism of ore and gneisses. Epigenetic hypotheses are advanced by Lundbohm, von Post and Löfstrand, the latter two considering the deposit as a magmatic dike. For the latter view speaks the tectonic relationship; the ore body is by no means attached to a single horizon in the gneiss. The country rock is probably a schistose, soda-rich igneous rock. On the whole the analogy with Kiruna is very striking. At both places the same genetic relations seem to exist; at first a soda-rich igneous rock of low to medium acidity, then follows an intrusion of ore-magnetite-apatite rock, lastly a quartzose soda-rich igneous rock was intruded.

Gellivare is then simply a dynamo-metamorphosed Kiruna.

W. LINDGREN.

RECENT LITERATURE ON ECONOMIC GEOLOGY.

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SCIENTIFIC NOTES AND NEWS[1]

THE NINETEENTH MEETING of the Geological Society of America and the meeting of the American Association for the Advancement of Science were held in New York on the 26th to the 29th of December. The meetings were largely attended by the working geologists of the United States and Canada and many valuable papers were presented. Those of greatest interest to students of economic geology were:

Geologic Map of North America, by Bailey Willis.
The Geologic Folio, by W. H. Hobbs.
The Cobalt, Ontario, Silver Area, by W. G. Miller.
The Virginia Barite Deposits, by T. L. Watson.
The Controlling Factors of Artesian Flow, by M. L. Fuller
The Galena Series, by Frederick W. Sardeson.
Coal Measures and Higher Beds of South Brazil, by I. C. White.
Origin of the Lead and Zinc Ores of Missouri, by E. R. Buckley.
Occurrence of Diamonds in North America, by George F. Kunz.

THE PHILIPPINE Miner's Promotion Association has been organized in Manila for the purpose of disseminating literature throughout the islands and in the United States setting forth the general mineral resources of the archipelago. The officers are as follows:—Governor-General James F. Smith, honorary president; George Landers, president; M. A. Clarke, vice-president; N. B. McCoy, second vice-president; C. E. Hamilton, third vice-president; Captain Collette, fourth vice-president; George Morgan, treasurer; Chauncey McGovern, secretary.

W. H. EMMONS, of the U. S. Geological Survey, having com-

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.

pleted the survey of the Philipsburg quadrangle, Montana, is now engaged in areál work at Bullfrog, Nevada.

FRANK L. HESS, of the U. S. Geological Survey, is in California, examining the scattered deposits of magnesite, and later will make a reconnaissance of the mineral deposits in the Llano district, Texas. This is an area of pre-Cambrian rocks in which iron and precious metals are reported.

DURING THE LATTER PART of the past summer Dr. Whitman Cross, of the United States Geological Survey, and his assistants, Albert Johannsen and L. H. Woolsey, made a preliminary reconnaissance of the San Cristobal quadrangle, Colorado, followed by a detailed survey of the Lake City district to the north. The reconnaissance was necessary in order to correlate the volcanic formations of the Silverton area with their equivalents about Lake City, where the geologic relations and lithologic characters of the beds are in a large measure new and unusually complicated. The Lake Fork extension of the Animas Forks mining district was also investigated during the reconnaissance and several lead-silver properties were visited, but the remainder of the season was devoted to detailed study and mapping of the Lake City quadrangle, especially along Henson Creek and the Lake Fork of the Gunnison. This area promises to be the key to many of the unknown features of the San Juan igneous complex, for the various flows, tuffs, and intrusions which have been traced over several quadrangles, here exhibit missing links in their geologic history.

PROFESSOR HANS HOEFER of Leoben, Austria, is preparing an exhaustive treatise or monograph on the occurrence and origin of Petroleum. Professor Hoefer's work on the subject of petroleum is well known and he may be mentioned as one of the ablest exponents of the organic theories of the origin of oil. Geologists will look forward with much interest to the appearance of this monograph. He is extremely anxious to receive copies of all papers on the subject of petroleum, asphalt, ozocerite and related products, and we are glad to give space to his request that copies of papers on oil occurrences in the English speaking countries be sent by the authors for reference and consultation to his

address at Leoben, Austria. He will be much facilitated in the preparation of his monograph if English and American authors will extend him this courtesy.

CHARLES BUTTS, of the United States Geological Survey, assisted by Chester Washburn and William S. Prouty, this season finished the field work on the Birmingham and Bessemer special quadrangles in Alabama. These two sheets include practically all the important coal and iron developments in the State, and, as is well known, are particularly important because, here within a limited area, are immense quantities of soft coal, iron ore and fluxing limestone. E. F. Burchard was associated with Mr. Butts in this field and devoted his time to an investigation of the economics of the iron deposits, and traced the boundaries of the Clinton or Rockwood formation. He also collected considerable technological data on iron mining and smelting.

THE EASTERN COAL DIVISION of the U. S. Geological Survey, working in Pennsylvania, completed the field investigation of three quadrangles during the past season. These are the Johnstown quadrangle, done by W. C. Phalen with the assistance of Lawrence Martin; Clarion quadrangle, by E. F. Lines, and the Sewickley quadrangle by M. J. Munn. Special attention was given to the accurate determination of the structure in this region, which is important for its coal resources.

GEORGE H. ASHLEY, chief of the eastern coal work of the U. S. Geological Survey, reviewed the geology of the Punxsutawney, Curwensville and Houtzdale quadrangles of Pennsylvania and settled several questions which had arisen in the survey of these quadrangles. The Houtzdale has given some trouble because it is an area of extensive faulting, of variable stratigraphy, and of almost no outcrops. Ashley and Phalen also completed the field work on the Kenova quadrangle, which lies largely in Kentucky.

THREE OF THE GEOLOGISTS of the U. S. Geological Survey have resigned this summer to enter private work. Their withdrawal is wholly due to the inability of the Government bureau to pay the salaries offered by mining companies. J. E. Spurr and G. H. Garry are with the Guggenheims. W. H. Weed resigned to accept a position as mining geologist with the Gen-

eral Development Company, 42 Broadway, New York. He has just returned from examining copper deposits in Mexico and British Columbia and is now in New York.

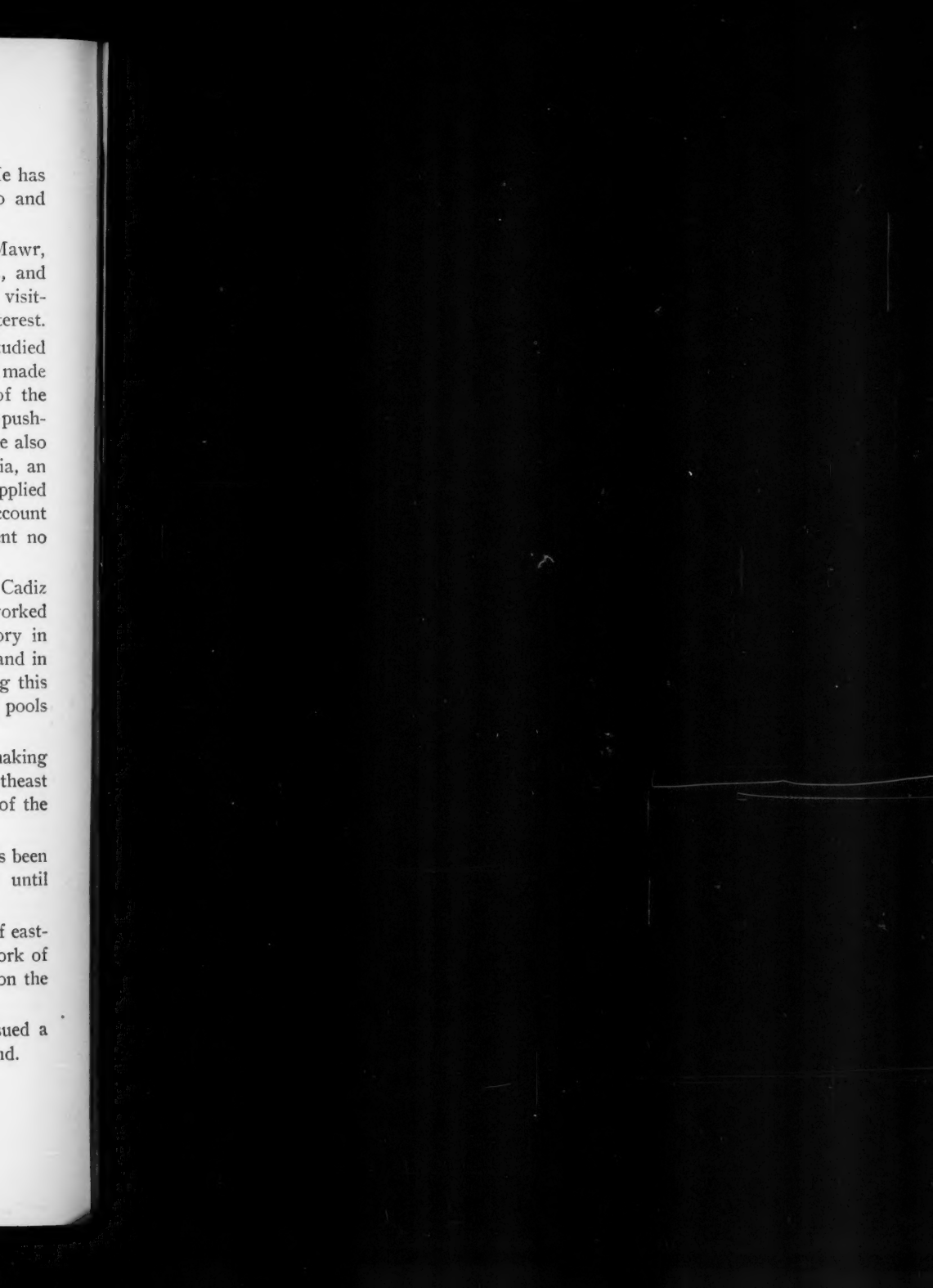
MISS FLORENCE BASCOM, professor of Geology at Bryn Mawr, was in Washington during December on official business, and sails for Europe in January. She will spend several months visiting German universities and localities of special geologic interest.

THE ELKHORN COAL FIELD in Pike County, Ky., was studied during the past season by R. W. Stone. This field was made accessible in June 1906, by the completion of a branch of the C. & O. railroad from Ashland. Several mines are rapidly pushing their development and have begun shipping. Mr. Stone also made a reconnaissance through Dickinson County, Virginia, an area of several hundred square miles which is abundantly supplied with bituminous coal, but as yet has not been developed on account of a lack of transportation facilities, there being at present no railroad within the boundaries of the county.

THE FLUSHING QUADRANGLE in Ohio, which joins the Cadiz on the southwest, was surveyed by W. T. Griswold, who worked out the structure in extreme detail. As this is a territory in which there is some prospect of finding gas and oil pools, and in which, as yet, there has been very little development along this line, it will afford an opportunity to predict the location of pools by a study of the structure previous to actual development.

C. E. SIEBENTHAL, of the U. S. Geological Survey, is making a special study of the lead and zinc deposits in the northeast corner of the Indian Territory, the southern continuation of the Joplin district, and will be in the field until February.

F. L. RANSOME, of the U. S. Geological Survey, who has been delayed by an accident, will be in Goldfield, Nevada, until January.

T. NELSON DALE has completed a study of the granites of eastern New England, which is a continuation of the field work of the previous year on the granites of Maine. The report on the latter subject is now ready for the printer.

THE MARYLAND GEOLOGICAL SURVEY has recently issued a report on the Pliocene and Pleistocene Deposits of Maryland.